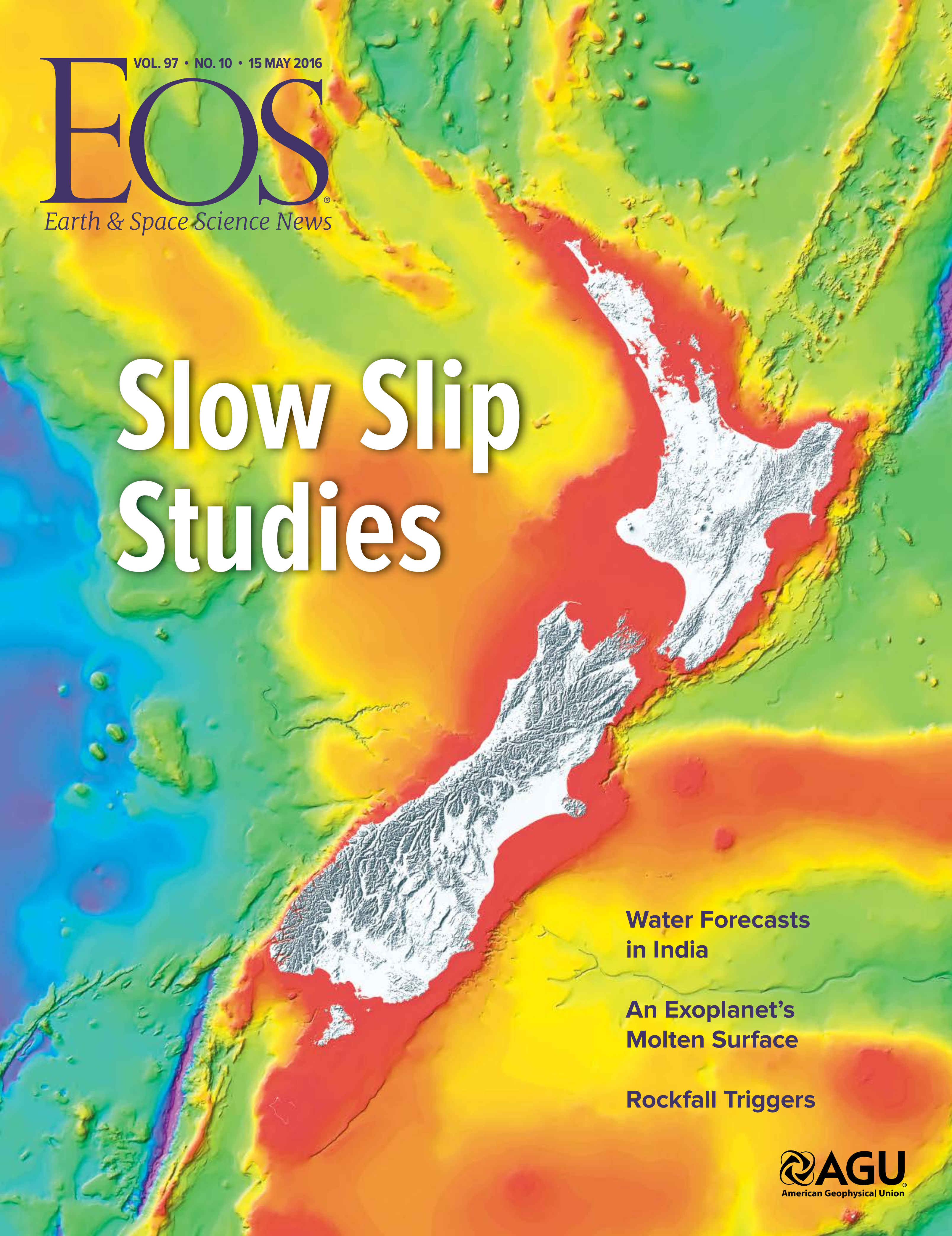
VOL. 97 • NO. 10 • 15 MAY 2016

EOS
Earth & Space Science News



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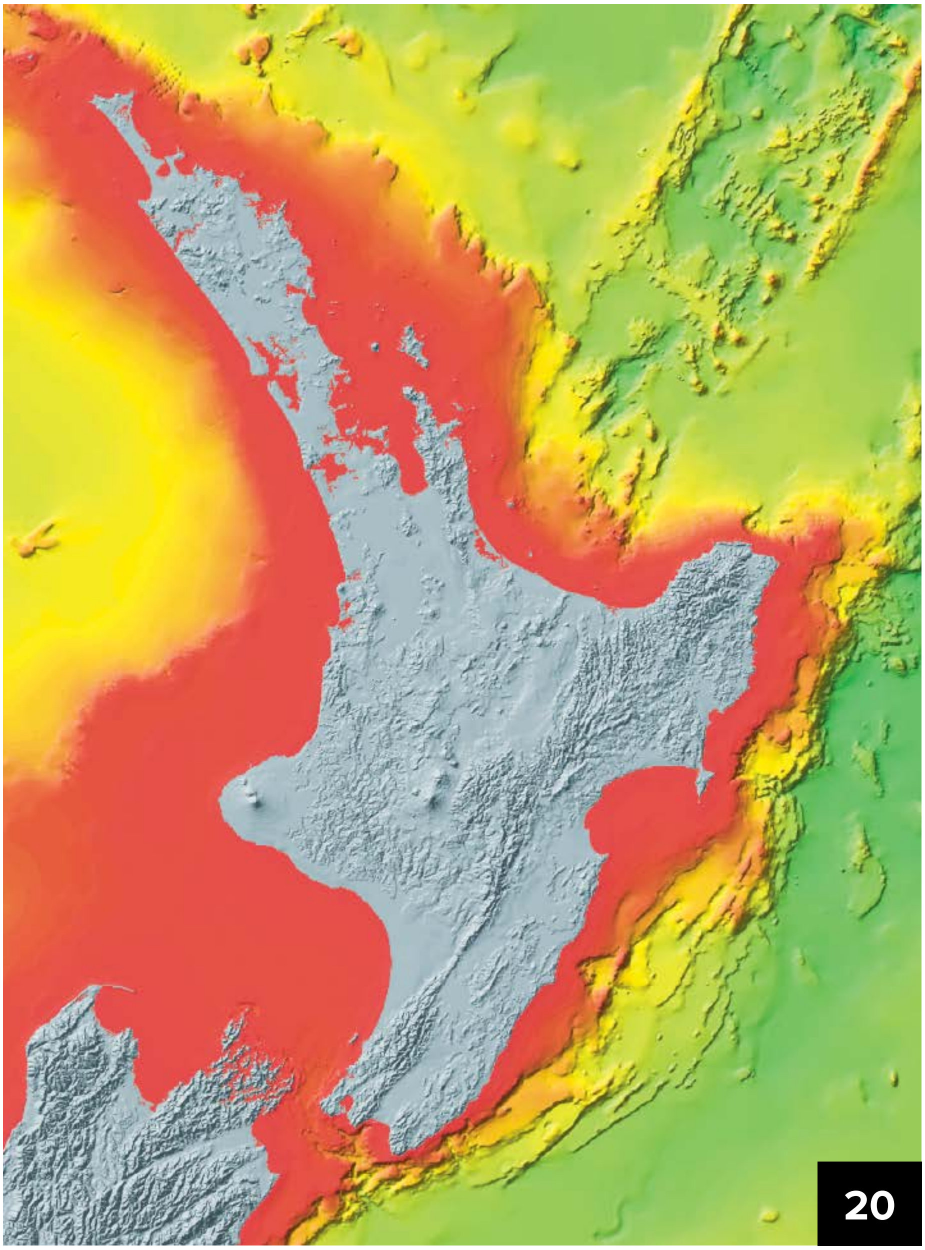

DEPARTMENTS

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On the Cover
Bathymetry around New Zealand. Credit: National Institute of Water and Atmospheric Research.

Eos®

Eos (ISSN 0096-3941) is published semi-monthly, on the 1st and 15th of the month by the American Geophysical Union, 2000 Florida Ave., NW, Washington, DC 20009, USA. Periodical Class postage paid at Washington, D. C., and at additional mailing offices. POSTMASTER: Send address changes to Member Service Center, 2000 Florida Ave., NW, Washington, DC 20009, USA.

Member Service Center: 8:00 a.m.–6:00 p.m. Eastern time; Tel: +1-202-462-6900; Fax: +1-202-328-0566; Tel. orders in U.S.: 1-800-966-2481; Email: service@agu.org.

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Christine W. McEntee, Executive Director/CEO

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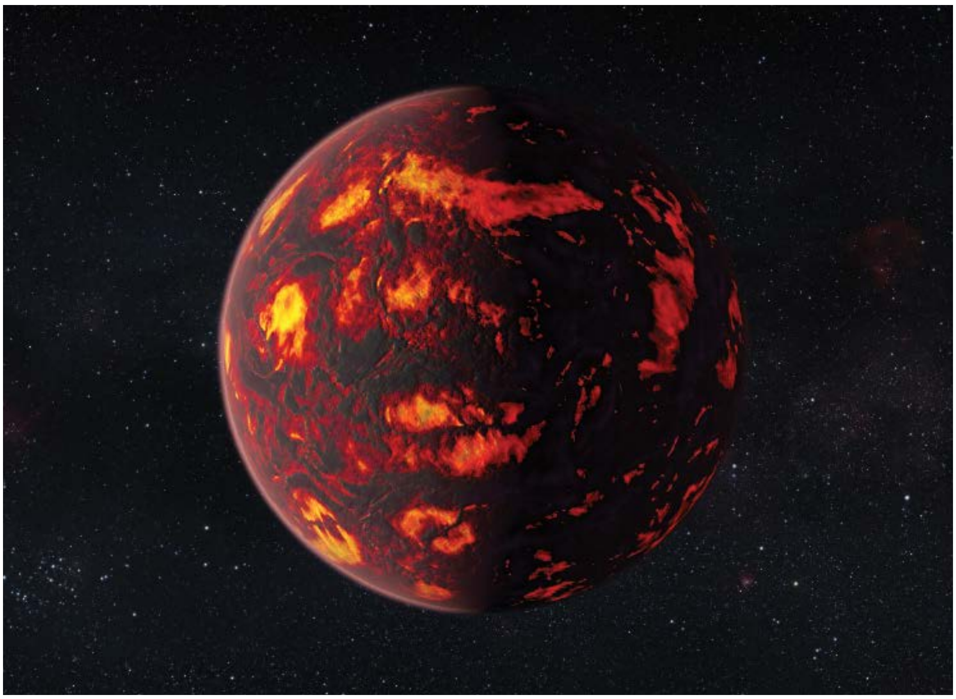
Space Telescope Findings Suggest Molten Planetary Surface


ESA/Hubble, M. Kommesser

An artist's representation of 55 Cancri e, which orbits a star 40 light-years from Earth in the Cancer constellation. The planet, which has an 18-hour "year," may have lava flowing over much of its surface.

One of the closest super-Earths, 55 Cancri e, may have flowing lava over a vast expanse of its surface according to a new thermal map—the first of its kind.

The exoplanet resides in a solar system 40 light-years away from ours and orbits its star every 18 hours, 70 times closer to it than Earth is to the Sun. It is no surprise that the planet is roasting, but over the past decade perceptions of 55 Cancri e have changed dramatically.

When scientists discovered the planet in 2004, they were unsure whether it was a smallish gas giant or a large rocky planet. In 2011 the planet's transit—when it passes between its star and the Earth—revealed that it was roughly twice the size of Earth and about 8 times the mass, putting it into the super-Earth category.

At the time, measurements suggested a thick atmosphere of water vapor or carbon dioxide surrounding a rocky inner body. However, that theory was scrapped when better measurements of the planet ruled out water vapor in the atmosphere.

Other scientists then suggested the planet consisted of primarily carbon—as opposed to the Earth's oxygen-rich interior—in the form of graphite and diamond, and thus it was dubbed the "diamond planet" (see http://bit.ly/Diamond-Planet). These findings have also been called into question.

In a paper published in late March in *Nature* (see http://bit.ly/Super-Earth-map), researchers suggest something new—that the planet's surface could consist largely of flowing lava.

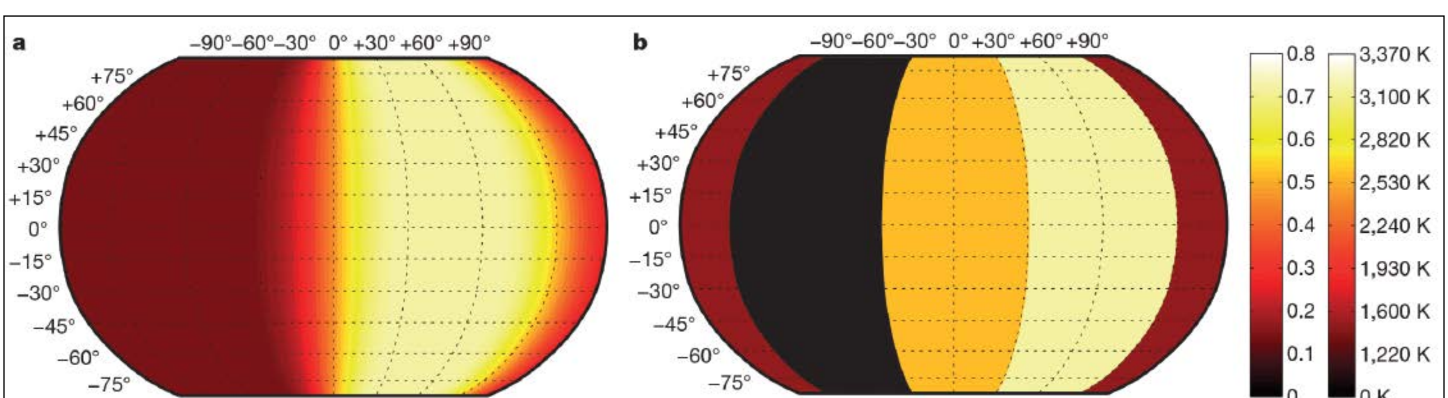
Super-Earths are all over the galaxy but are absent from our own solar system, so exploring this solar system diversity can give us clues about solar system formation and planet migration, said Brice-Olivier Demory, an astrophysicist at the University of Cambridge in the United Kingdom and lead author on the paper.

Lava World

Demory and his team used the infrared camera aboard the Spitzer Space Telescope, which orbits Earth, to observe 55 Cancri e. The telescope took millions of measurements of infrared light from the planet as it revolved multiple times around its star in 2013.

Because the planet is tidally locked, meaning that one side always faces the star and one side faces away—just like our own Moon—only the nightside was visible as the planet transited its star. The observers could view the dayside of 55 Cancri e only just before and just

A longitudinal heat map of 55 Cancri e, created by Demory and his colleagues. The yellow portions represent hotter temperatures, which are offset from the center. This offset suggests the presence of flowing lava.



Demory et al., 2016, doi:10.1038/nature17169

after the planet passed behind the star. The infrared camera is especially sensitive to temperature variation, which allowed the researchers to build the first thermal map of a super-Earth, Demory said.

Surprising Features

The map revealed surprising features reported in the new paper: First, the dayside temperature of 55 Cancri e, about 2700 kelvins (2427°C), surpassed its nightside temperature by about 1300 K (1027°C). This pattern casts doubt on the existence of a thick atmosphere, which would have circulated the heat relatively evenly around the planet, Demory said. Second, the researchers found that the hottest spot on the planet, which they expected to be centrally located on the dayside, appears about 41° of longitude to the east.

"We may have a bit of [heat] circulation on the planet, not from the atmosphere but mainly from lava," Demory explained. At the searing dayside temperatures, silicate-based rocks are molten—as they are below the crust on Earth. On 55 Cancri e's dayside, the researchers suggest the lava could be flowing almost like water. As the planet orbits the star, the lava would flow toward the nightside, where it would cool significantly and thicken, possibly even solidifying.

Large, gassy exoplanets called "hot Jupiters" exhibit similar flow dynamics of gases, Demory said, with a hot spot offset from the center.

"The suggestion of lava flow is intriguing—this is something that has never been detected before."

"The suggestion of lava flow is intriguing—this is something that has never been detected before. If the response to this high-temperature environment really is extrusion of molten lava, this gives us information about the internal structure of this unseen planet," said Debra Fischer, an astronomy professor at Yale University in New Haven, Conn., who wasn't involved in the research. "The analysis is beautiful, and alternative explanations have been carefully considered."

Planetary Implications

"A study like this that hones in on one planet may seem limited in scope but is actually critical to our understanding of super-Earths because there are still only a handful of these planets that are characterizable in such detail," said Johanna Teske, an astronomer at the Carnegie Institution of Washington in Washington, D. C., who also wasn't involved in the paper.

Many more observations are needed to confirm the presence of lava and to better understand the planet, Demory said. The fact that super-Earths are relatively common in the galaxy makes "us wonder why we don't have any" in our own solar system, he continued. Studying planets like this is "paramount to better understanding our own origins."

By **JoAnna Wendel,** Staff Writer

U.S.-Cuba Scientific Cooperation Revs Up

John Brooks/National Park Service

Under a recently established U.S.-Cuba collaboration, the countries will share research and protect sensitive waters, including those of the coral reef–rich Biscayne National Park.

When Joe Roman thinks about Guantánamo Bay, he sees an opportunity to turn a symbol of U.S.-Cuba tensions into a scientific engine of diplomacy. The University of Vermont conservation biologist and a colleague want to turn Guantánamo military base and detention center into a peace park and a research facility where U.S. and Cuban scientists could study issues both countries share, from climate change to coral reef preservation to marine pollution.

He admits the vision is a long shot right now—the United States isn't closing Guantánamo and returning it to Cuba anytime soon, for one. However, the recent thaw in U.S.-Cuba diplomatic tensions gives him hope. "I see it being a win-win for both countries and for the region in general," Roman told *Eos*.

Roman's spirit echoes growing optimism among scientists in a time of rapprochement highlighted by President Barack Obama's visit to Cuba in March. Many marine and Earth scientists say the U.S. reengagement with Cuba under Obama is sowing the seeds for a new era of scientific collaboration.

Although Obama's actions haven't removed every barrier and other challenges lie ahead, the movement toward cooperation is picking up pace. This is giving scientists hope. "I don't think we ever thought the change would happen this fast," Fernando Bretos, a marine scientist and director of the Miami-based Cuba Marine Research and Conservation Center (Cubamar), told *Eos*.

The scientific equipment policy is arguably the most critical change for scientists.

Cold War Chill

Ever since a trade embargo and other restrictions were placed on Cuba during the Cold War, Americans, including scientists, have needed to obtain special permissions and visas to travel there. Also, U.S. law has strongly restricted shipments of scientific equipment to Cuba and the use of federal funds for research done with Cuban scientists.

Likewise, Cuban scientists have faced their own nation's restrictions on working with U.S. scientists, traveling to conferences, and using boats for research, according to marine scientist David Guggenheim, president of the Washington, D. C.-based nonprofit organization Ocean Doctor.

The restrictions had long made collaboration logistically challenging and psychologically frustrating, according to Daria Siciliano, a Cubamar associate of Bretos's and a coral reef biogeochemist and ecologist at the University of California, Santa Cruz. Familiar with that frustration, atmospheric scientist Alan Robock of Rutgers University in New Brunswick, N.J., recounted to *Eos* that it took 20 years to get one water vapor monitoring station installed on the island.

However, Obama has gradually loosened constraints on travel to Cuba for research activities, educational exchanges, and other purposes. Last year, the Commerce Department lifted restrictions on donations of scientific equipment to Cuba for nonmilitary uses (see http://bit.ly/limits-eased).

The scientific equipment policy is arguably the most critical change for scientists, says Guggenheim, who has visited Cuba more than 80 times. High-quality equipment taken for granted in the United States—from mass spectrometers to microscopes—is lacking in Cuba, scientists say.

The Obama administration has also made it easier for Cuban scientists to obtain visas to travel to the United States, Guggenheim said. "That's dramatically changed our ability to work together," he told *Eos*.

Unofficial Ties Lead the Way

A lot of the bricklaying for future collaboration started behind the scenes before the governments started reengaging. Individual scientists have collaborated for more than 20 years despite diplomatic silence between the United States and Cuba, Frances Colón, a science adviser at the State Department, told *Eos*.

Mexican and Cuban nonprofit groups and scientists have also, more formally, met since 2007 to promote environmental and marine science collaborations. U.S. officials couldn't join these talks initially. However, Siciliano argued that these meetings helped lead to a November 2015 U.S.-Cuba memorandum of understanding on environmental protection—not even a year after the countries normalized relations in December 2014. In the agreement, the countries pledge to, among other things, "strengthen cooperation on sci-

entific research" into climate change, pollution, and conservation.

Some of this government-initiated collaboration is already under way, according to the National Oceanic and Atmospheric Administration. The countries agreed to share research, initially focusing on five sensitive areas of the Caribbean Sea to protect them better. Collaborative fisheries and oceanographic research is also in the works; last year, U.S. scientists completed an oceanographic survey with Cuban colleagues in areas of the Caribbean, the Gulf of Mexico, and the Florida Straits. The White House said in March that it would convene a working group to find more collaboration areas.

Fragile Bonds

Some barriers remain. Continuing restraints on federal funding for research with Cuban scientists may limit how much collaboration can occur. Also, unless Congress ends the trade embargo, scientists can't move equipment to Cuba on ships outbound from the United States; scientists must still use costly, logistically complicated shipping methods like chartered air flights or Cuba-bound ships from different countries, Bretos says.

Adding to these U.S. hindrances, the Cuban side presents some of its own—for instance, a skeptical military that may suspect that technology given or donated to scientists is destined for nefarious uses such as spying, said Robock. He has visited Cuba repeatedly and chatted with former president Fidel Castro about Robock's research on nuclear winter.

The longevity of U.S. overtures also remains uncertain. Dan Whittle, senior director of the Environmental Defense Fund's Cuba program, noted that with just months to go in Obama's presidency, a future president of the opposing party could roll back his actions. "A lot more needs to be done on the ground to make those changes irreversible," he told *Eos*.

Colón acknowledged the possibility of a rollback, but she argued that scientific collaboration benefits all. "Science is not something that should be caught up in political debates," she said.

Scientists realize they need to play the long game. Nothing may exemplify the long game more than the Guantánamo proposal. Even with the progress made recently, scientists can only imagine what the Guantánamo proposal might do. "Science diplomacy works," said Bretos, who isn't involved in the proposal. "It can bring countries together."

By **Puneet Kollipara,** Freelance Writer; email: puneet.kollipara@gmail.com

A Warm Day Can Trigger Rockfalls

Valerie Zimmer, National Park Service

Researchers Brian Collins and Greg Stock download data that indicate how much partially detached granitic slabs on a mountain face have moved as a result of daily temperature variations. Such movement is a precursor to a rockfall.

Geologists have long known that earthquakes, along with precipitation and freeze-thaw cycles, can trigger giant slabs of rock to fall from mountain faces, to thunderous effect. Now a research team, following a clue from rock climbers at Yosemite National Park, has shed some light on why rockfalls will sometimes happen in the middle of a clear, sunny day without an obvious cause.

The reason? Daily, seasonal, and annual temperature fluctuations can cause the granite slabs to slowly peel away, or exfoliate, then suddenly fracture and fall, the scientists reported recently in *Nature Geoscience* (see http://bit.ly/rockfall-trigger).

"There's this hypothesis that thermal stresses could cause rocks to fracture and break and fall. That isn't anything new—people have been thinking about that for over a hundred years. But it hadn't been measured," said Brian Collins, a research civil engineer with the U.S. Geological Survey in Menlo Park, Calif., and a coauthor of the 28 March paper.

Climbers Point the Way

Collins and coauthor Greg Stock, who is Yosemite's first-ever park geologist, had heard stories from Yosemite's many rock climbers about their climbing gear getting stuck in the cracks of detached granite slabs—or "flakes," as Collins and Stock say—as hot days wore on into cool nights. This gave the duo the idea to climb to a flake and install "crackmeters"—instruments the researchers devised themselves that measure minute changes in crack width over time.

"This isn't just [one person who] put the gear in wrong and couldn't get it back out; lots of people are going through this," Collins said. "We thought, maybe it's that the rock flakes are moving back into the cliff, and if that's the case, maybe it's measurable."

They specifically put the crackmeters in a gap behind a granite flake about 19 meters long, 4 meters wide, and about 15 meters above the park's valley floor. After 1 month, the crackmeter data indicated that the flake, from night to day, was moving "in and out of

Tom Evans

An exfoliation-type rockfall cascades from Yosemite Valley's El Capitan on a clear day in October 2010.

the wall by up to a centimeter each day," said Collins. "That was a big huge 'wow!'—we had no idea it was going to move that much."

Thermal Weathering

Ultimately, Collins and Stock monitored the crack for 3.5 years. Over that time, they found that crack widths vary seasonally, with the hot summer months producing the widest offsets. They also found that the rock's outward expansion was cumulative: The flake would move forward more and more each year, building on the previous season's progress.

Millions of people visit Yosemite every year, so the park's staff has kept thorough records of rockfalls there (see http://bit.ly/log-o-rockfalls). These records indicate that spontaneous rockfalls—the kind that happen for no obvious reason—occur most often during the hot summer months. "We discovered that these flakes actually deform quite a bit, much more than we had originally thought, and we've been able to link that to how the process of thermal heating can move a flake in and out," Collins said. Such movement will "eventually lead to fracture," he added.

Still, because fracture propagation is nonlinear, it is not possible to predict how far off in the future a flake might pass its threshold and detach, Collins explained.

"These results are scientifically wonderful, and they have implications for landscape evolution and rockfall hazards in other high-mountain areas," commented landslide expert David Petley of the University of East Anglia in the United Kingdom in a 30 March blog post about the new study.

"Whilst higher than expected levels of rockfalls have been observed in the summer months in many mountain landscapes, in general I think it has been assumed that this is mostly associated with the melting of ice in cracks. Whilst this ice-driven process is undoubtedly still important, Collins and Stock (2016) have given us cause to think about other processes too," added Petley, whose editorially independent *The Landslide Blog* (see http://bit.ly/Landslide-Blog) is hosted by AGU, publisher of Eos.org.

In future work, Collins explains, it may be possible to determine "how many [thermal] cycles it takes to eventually fracture the rock," which might help Yosemite's staff identify slabs that may be close to collapsing and thus endangering park visitors.

By **Lucas Joel,** Freelance Writer; email: lucasvjoel@gmail.com

Seven Ways Climate Change Threatens U.S. Population's Health

James Gathany, CDC/PHIL

Aedes aegypti *mosquitoes transmit* Flavivirus dengue *and dengue hemorrhagic fever. Climate change could increase human exposure to dengue in the United States, according to a recent report.*

Climate change imperils the health of every American, according to a recent report issued by the White House.

"Current and future climate impacts expose more people in more places to public health threats," states the scientific assessment by the U.S. Global Change Research Program (see http://bit.ly/Climate-Health). "Almost all of these threats are expected to worsen with continued climate change," notes the report, developed by more than 100 experts from eight federal agencies. Some more vulnerable segments of the population, including people with low incomes, some communities of color and immigrant groups, pregnant women, young children, and the elderly, face the greatest impacts.

The report's authors examined these climate change–related health risks for the past 3 years to update 2008 and 2014 U.S. government studies (see http://bit.ly/2008-Report and http://bit.ly/2014-Health).

"It's not just about polar bears and melting ice caps. It's about our kids, it's about our families, it's about our future," Environmental Protection Agency (EPA) administrator Gina McCarthy said at a 4 April White House event to release the report. EPA led the development of the report along with the National Oceanic and Atmospheric Administration and the Department of Health and Human Services.

McCarthy said she hopes the report can "jump-start the conversation about the dangers of inaction" and ignite a "call to action" in response to the public health risk.

Here are seven angles on the climate change health threat among many covered by the report:

1 Temperature-related illnesses and deaths. With climate change increasing the frequency and severity of extreme heat events, heat-related premature deaths during summers will rise by thousands to tens of thousands. Uncertainty about how well people will adapt to extreme heat through air conditioning, acclimatization, and other factors limits how precisely researchers can predict the death toll. At the rollout of the report, White House science adviser John Holdren said the increased heat-related mortality "will be a really big deal in the hottest parts of the United States, as well as in the Middle East and South Asia and other places." Projections indicate a corresponding but smaller decrease in cold-related premature deaths during winter.

2 Air quality. Climate change will make meteorological conditions more conducive to the formation of ground-level ozone, a respiratory irritant. It will also roil weather patterns that affect the levels and locations of ozone and other air pollutants, making it harder for any particular regulatory scheme to reduce ozone. Rising temperatures, altered precipitation patterns, and increasing concentrations of atmospheric carbon dioxide likely will contribute to increases in some airborne allergen levels. That could lead to "longer and more intense allergy seasons," Holdren said.

3 Extreme weather. Projected increased frequency and severity of some extreme forms of weather likely will make coastal populations more vulnerable to health impacts from flooding, and damage power, water, and communications systems and other infrastructure essential to public health and emergency response.

4 Vector-borne diseases. Climate change likely will expand the geographic range of vectors such as mosquitoes, ticks, and fleas and the time periods when they can transmit illnesses, although better vector control and personal protection measures could help slow the rise of disease transmission rates.

5 Water-related impacts. More frequent extreme weather events and storm surges will heighten the potential for key infrastructure for drinking water, wastewater, and storm water to fail because of damage or overcapacity. Water infrastructure failures and higher water temperatures could increase human exposure to contaminants that cause illness, such as pathogens and toxic byproducts of harmful algal blooms.

6 Food and nutrition. In addition to disrupting food production, prices, and trade in the United States and globally, climate change also likely will increase pathogens and toxins in food. Moreover, rising levels of carbon dioxide are very likely to lower the nutritional value of food, including wheat and rice, by reducing plant species' concentrations of protein and essential minerals.

7 Mental health. Many people exposed to climate-related or weather-related disasters experience mental health consequences, according to the report. Those consequences include post-traumatic stress disorder, depression, and general anxiety.

By **Randy Showstack,** Staff Writer

Sound Waves Help Scientists Track Volcanic Eruptions

ISS CEO ISAL, JSC

Astronauts aboard the International Space Station photographed Pavlof volcano as it erupted on 18 May 2013. In a successful test of a new volcano-monitoring technique, researchers at the Alaska Volcano Observatory found that they could accurately locate this eruption using acoustic signals known as ground-coupled airwaves that they filtered from seismic data.

Deep in the Alaska wilderness, explosive volcanoes that can be a threat to aviation are hard to monitor, much less reach. Although seismometers provide valuable insights from a volcano's deep rumblings, seismic data alone can be lacking regarding other important features, such as aboveground explosions. And because of frequent cloud cover, sometimes even satellites offer no help.

Because of these monitoring challenges, scientists at the Alaska Volcano Observatory (AVO) have now turned to a phenomenon that is well known but not normally used to detect or observe volcanoes—sound waves that eruptions blast into the air and that later hit the ground and convert into seismic waves.

The AVO scientists can use these so-called ground-coupled airwaves (GCAs) to spy on volcanic activity thanks to a new way of teasing acoustic information from seismometers that the scientists are already using to gather ordinary seismic information about volcanoes.

"In a perfect world, your seismometer would only record seismic waves and your acoustic sensor would only record the acoustic waves."

"In a perfect world, your seismometer would only record seismic waves and your acoustic sensor would only record the acoustic waves," and there would be enough of both instruments to gather all the data needed, said David Fee, a seismologist at the Alaska Volcano Observatory and the University of Alaska Fairbanks. But because their supply of acoustic sensors is thin, Fee and his colleagues decided to "push the seismic data" as much as they could to extract GCA signatures from their seismic instruments. The researchers report their new approach in a paper published in early April in the *Bulletin of the Seismological Society of America* (see http://bit.ly/GCA-paper).

This extra processing will provide helpful additional information for tracking and monitoring eruptions, particularly if acoustic sensors aren't deployed, Fee said. Such information could be especially important in cases of large eruptions that produce a lot of ash, which can damage commercial airplanes by getting sucked into the engines.

Volcanos' Sound Waves

When a volcano erupts, a fraction of the huge burst of energy propagates away from the scene as seismic waves through the ground. Some of this energy also travels through the air as acoustic waves.

The acoustic waves can travel thousands of kilometers, depending on the size of the eruption. When these waves hit the ground, they convert into ground waves that shake a seismometer much like earthquake waves do.

Scientists have observed this phenomenon for "a number of years," Fee said, but "most of the time people kind of ignore them or disregard them." Seeking ways to overcome their observational challenges, from cloudy skies to the absence of local networks of seismometers at some volcanoes, Fee and his colleagues decided to see if they could locate and characterize volcanic eruptions using GCAs.

The researchers studied 6 years of seismic data from eruptions of the Veniaminof and Pavlof volcanoes, as well as the Aleutian Arc's Cleveland volcano. Although it's difficult to pick out the GCA data from the seismic wave data, Fee said, it's not impossible. Acoustic waves travel 10 times slower than seismic waves, so Fee and his colleagues could "tune" their data analysis to extract the acoustic waves from the jumbles of seismic data.

To then locate the volcano, they used methods employed by seismologists—except applied to GCAs—to track down the epicenters of earthquakes, Fee explained. Those methods involved measuring the time it took for each wave to arrive at several seismic stations around the volcano. The timing measurements, in turn, enabled the team to pinpoint the eruption. For all three volcanoes, the researchers report in their 5 April study, they were able to work backward using GCA data to locate the sources.

This method will be especially helpful when monitoring volcanoes on the far-away Aleutian Arc that are outside of a seismic network.

Detecting Eruptions

This method will be especially helpful when monitoring volcanoes on the far-away Aleutian Arc that are outside of a seismic network, Fee said. Seismic shaking followed by an acoustic signature could help monitoring stations to know whether the blips they see are from an earthquake or an eruption. The acoustic data will also give scientists a better idea of what's going on above ground—such as whether there was an eruption that produced large clouds of ash—rather than just below ground, where subsurface activity generates only seismic waves, Fee said.

"For detecting explosions, particularly the large and probably big ash producers, having [these GCA data] in their quiver of tools should be really useful, particularly when the weather—Alaska does have bad weather—makes other techniques for seeing the start of ash clouds difficult," said Steve Malone, former director of the Pacific Northwest Seismic Network and emeritus professor at the University of Washington in Seattle, who wasn't involved in the research. "From my perspective, more important than additional research is to now put the appropriate techniques into operational use at AVO."

There are a few confounding factors, however—volcanic eruptions aren't the only sources of GCAs; rock falls, ocean waves, and meteors produce them as well. Luckily, researchers can use the size of the signature—rockfalls wouldn't create intense shaking—and the precise locations of known volcanoes to help determine if detected GCAs trace back to an eruption.

Scientists at the AVO are already using GCA data to monitor eruptions, Fee said. Although he is confident that the process works, there are some caveats. Some volcanic eruptions, like Pavlof's most recent outburst at the end of March, proceed as a muted rumble with relatively little acoustic energy compared to seismic energy, so any GCA data get overcome by the seismic data, Fee said.

By **JoAnna Wendel,** Staff Writer

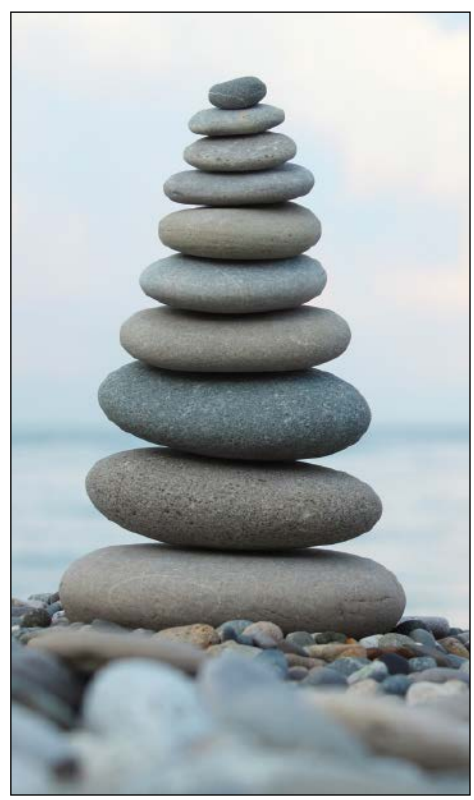
Honoring Earth and Space Scientists

The U.S. government's Science Envoy Program has selected five preeminent scientists to use their scientific expertise to forge international cooperation. As a science envoy, **Margaret Leinen,** director of the Scripps Institution of Oceanography and president of AGU, will focus on building international relationships with Latin America, East Asia, and the Pacific. Other scientists chosen include **Daniel Kammen,** distinguished professor of energy at the University of California, Berkeley, and founding director of the Renewable and Appropriate Energy Laboratory, who will concentrate on energy innovation in the Middle East and Africa; **Thomas Lovejoy,** professor at George Mason University in Fairfax, Va., and senior fellow at the United Nations Foundation, who will handle biodiversity and wildlife conservation in Latin America, East Asia, and the Pacific; **Linda Abriola,** former dean of the Tufts University School of Engineering in Medford, Mass., who will devote her attention to the Middle East, North Africa, and south and central Asia; and **Mark Hersam,** director of the Materials Research Science and Engineering Center at Northwestern University in Evanston, Ill., who will focus on eastern Europe.

❖ "Hubble repairman" **John Grunsfeld** retired from NASA at the end of April, according to an agency announcement. Grunsfeld, associate administrator for NASA's Science Mission Directorate, previously served as a five-time space shuttle astronaut and as the agency's chief scientist. Grunsfeld flew more than 100 science missions, according to NASA. Notable science achievements under his leadership include the Curiosity rover Mars landing in 2012 and the July 2015 New Horizons Pluto flyby, which completed the initial reconnaissance of the solar system. Grunsfeld was the lead spacewalker during the final Hubble Space Telescope servicing flight in 2009, which successfully upgraded the observatory. **Geoff Yoder,** who had been the directorate's deputy, is serving as acting associate administrator until a successor to Grunsfeld takes office.

❖ **Lucy Jones,** dubbed the "earthquake lady," retired from the U.S. Geological Survey (USGS) on 30 March following a 33-year tenure during which she helped to demystify earthquakes for the general public. Jones, a seismologist with USGS and a visiting research associate at the Seismological Laboratory of the California Institute of Technology since 1983, served as science adviser for risk reduction in the USGS natural hazards mission and as lead for the agency's Science Application for Risk Reduction (SAFRR) project. However, she has not left the earthquake world. In a 3 April tweet, Jones wrote, "I'm retiring from @USGS, not going out to pasture. I'm writing a book, then starting a center to promote community resilience."

❖ **Xyoli Pérez-Campos** of the Department of Seismology of the National Autonomous University of Mexico (UNAM) in Mexico City has become the 2016–2017 president of the Mexican Geophysical Union (UGM), after serving 2 years as vice president and president-elect of UGM's 2014–2015 council. **Ligia Pérez-Cruz,** chair of the Department of Geomagnetism and Exploration Geophysics at UNAM, has become president-elect and vice president of UGM's new 2016–2017 council, which took office on 5 January. Pérez-Campos and Pérez-Cruz, who are both AGU members, participated in the Convocation of International Societies at the 2015 AGU Fall Meeting last December in San Francisco, Calif.



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Learning About Teaching: Geoscience Educators Share Insights

Earth Educators' Rendezvous
Boulder, Colorado, 13–17 July 2015

Poster hall at the first Earth Educator's Rendezvous. Geoscience education researchers interacted with geoscience faculty members who use this research in teaching their undergraduate classes.

The first ever Earth Educators' Rendezvous (see http://bit.ly/Earth-Ed-2015) brought together more than 300 professionals: geoscientists, psychologists, and academic faculty in the physical and social sciences and the humanities. The rendezvous provided a previously lacking venue for interaction between geoscience education researchers and the faculty who use this research in their teaching.

We focused on our role as educators and sought to improve opportunities for undergraduate students to learn about Earth. We examined courses with strong pedagogy and design that are grounded in research and that link learning about Earth to its societal context, as well as programs designed to maximize the success of all students.

The rendezvous was organized around geoscience education research results and their application in the classroom, practical knowledge for teaching geoscience, and strengthening geoscience programs. Many attendees played multiple roles in the program, a dynamic mix of workshops, working groups, plenary sessions, oral and poster sessions, and a concluding town hall meeting.

Cognitive psychologist Nora Newcombe delivered the opening plenary on the critical roles that cognitive science and geoscience education research (GER) can play in guiding instruction. Presentations, workshops, and a National Science Foundation–funded activity characterizing GER results brought participants up-to-date on research highlights, informed future research agendas, provided opportunities for increasing research skills, and recommended strategies for building a stronger GER community (e.g., developing a research methods "toolbox" for new GER workers).

Research findings on learning in the field, instructional strategies that promote conceptual change, and development of spatial thinking are important sources of information for faculty, as is information from other faculty on what is working in their teaching. Thus many participants attended to interact with other faculty and to learn how they teach different aspects of the geosciences. The rendezvous enabled this by offering sessions on course design, availability and use of large data sets, and teaching controversial topics.

Knowledgeable faculty and strong geoscience education research are necessary but are not sufficient to provide the educational opportunities needed for an Earth-literate public and a workforce that can address environmental challenges and resource needs. We must also have strong degree programs, supportive learning environments for students, teachers who can prepare and encourage younger students to pursue geoscience, and the ability to reach out to students who will never take a geoscience course. Rendezvous sessions covered strategies for supporting diverse students, the role of systems thinking, preparing future teachers, and strategies for program design. The importance of context in making science concepts accessible to all was of wide interest.

Participants at the concluding town hall meeting emphasized the value of the rendezvous as an opportunity to share, learn, and network. They stressed the importance of teaching that engages students in learning, they felt empowered and energized to try different approaches, and they recommended the rendezvous website as a resource for others interested in learning more.

Attendees gained insight into the role of societal context in enhancing learning, the promise of the Next Generation Science Standards (see http://www.nextgenscience.org) for increasing learning about Earth, and the importance of departments in supporting student and faculty learning. Registration is now open for the 2016 Earth Educators' Rendezvous (see http://bit.ly/Earth-Ed-2016), to be held 18–22 July in Madison, Wis.

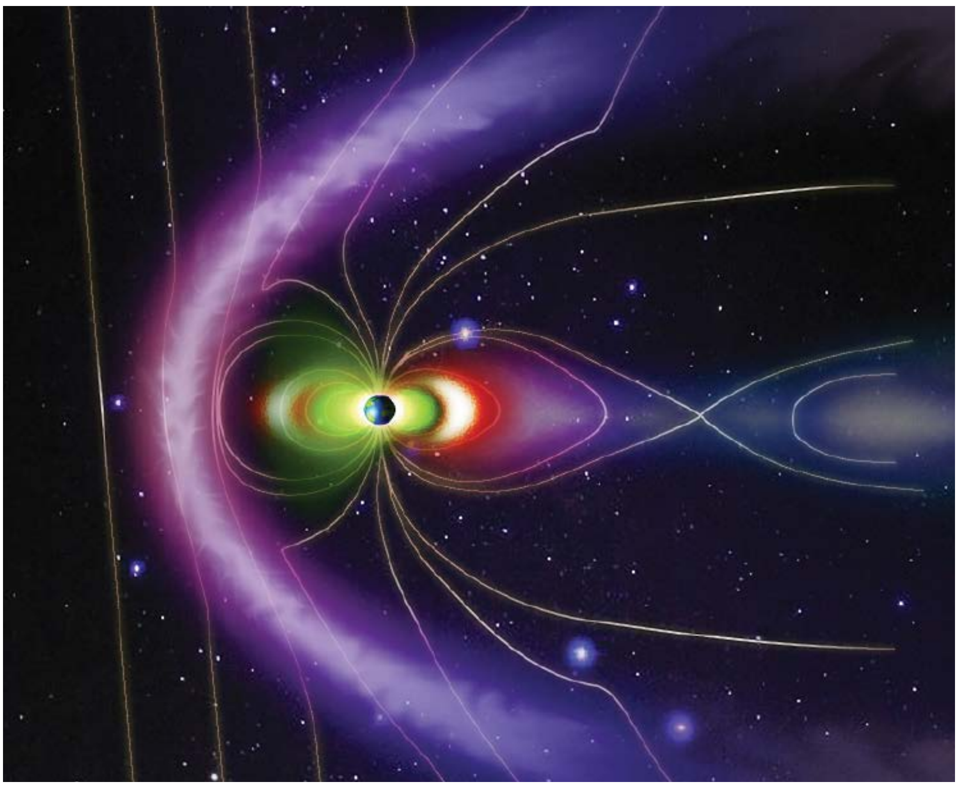
This meeting was organized by the On the Cutting Edge and Interdisciplinary Teaching about Earth for a Sustainable Future (InTeGrate) projects and was supported by participant registrations; contributions from AGU, the Geological Society of America, and the National Association of Geoscience Teachers; and grants from the National Science Foundation.

By **Cathryn A. Manduca,** Science Education Resource Center, Carleton College, Northfield, Minn.; email: cmanduca@carleton.edu; **R. Heather Macdonald,** Department of Geology, College of William and Mary, Williamsburg, Va.; and **Laurel Goodell,** Department of Geosciences, Princeton University, Princeton, N.J.

MEETING REPORT

Exploring New Knowledge on Magnetospheric Interactions

AGU Chapman Conference on Magnetospheric Dynamics
Fairbanks, Alaska, 27 September to 2 October 2015



Jerry Goldstein

Participants at last year's Chapman Conference discussed new insights on interactions between the Sun's and Earth's magnetic fields (shown here as white lines), which result in geomagnetic activity and auroras that are visible from Earth's surface. Similar processes occurring at other planets, notably Jupiter and Saturn, were also discussed at the meeting.

Fairbanks, Alaska, offers auroral viewing possibilities at the place where Sydney Chapman spent a large part of his career. This venue, along with our anticipation of new knowledge expected from the Magnetospheric Multiscale (MMS) mission on how magnetic field lines from the Sun and Earth connect and the impending arrival of NASA's Juno spacecraft at Jupiter's magnetosphere on 4 July 2016, provided a perfect confluence of factors for our fall 2015 review of magnetospheric dynamics. The Chapman Conference format proved to be ideal: More than 100 participants engaged in an intense 5-day discussion of all aspects of magnetospheric physics, culminating in an all-day discussion of the preliminary results of MMS.

On Monday, the first day, Vytenis Vasyliunas presented a keynote lecture on comparing magnetospheres. Fran Bagenal and Peter Delamere followed up with perspectives on expected Juno contributions. They also compared the interactions of the solar wind with the giant planets' magnetospheres and with Earth.

The speakers discussed how the magnetospheres of Saturn and Jupiter are driven mainly by planetary rotation but also have important reconnection phenomena (the Vasyliunas and Dungey cycles, which involve reconnection along a stretched closed field line and reconnection of two open field lines, respectively). These cycles cause plasma circulation in the magnetosphere and dynamic auroral displays, which offer many opportunities for comparison with Earth's magnetosphere.

In Tuesday's keynote lecture, Jim Drake identified two fundamental routes to fast reconnection: through the formation of a steady open outflow channel (from Hall reconnection, where ion dynamics control the reconnection rate, and through the formation of a bursty outflow channel in which magnetic islands carry plasma downstream). This talk was followed by Paul Cassak's discussion of the asymmetric reconnection phenomena that occur at Earth's dayside magnetopause.

Also on Tuesday was Li-Jen Chen's presentation of preliminary MMS electron-scale measurements in a possible reconnection diffusion region, in which magnetic energy is converted to particle energy, causing the magnetic field lines in the solar wind and the magnetosphere to break and reconnect, one to the other. Jimmy Raeder and Yu Lin presented global magnetosphere modeling results. Afterward, Amitava Bhattacharjee discussed the integration of kinetic effects into these models.

On Wednesday, Howard Singer gave a keynote talk on space weather, and Bob Schunk brought us up-to-date on the theory and modeling of ionospheric outflow and its effects on the magnetosphere. A record-setting 16-inch (0.4-meter) September snowstorm that morning knocked out power to the meeting hotel for 9 hours. No sessions were planned for that afternoon, thankfully. After the weather cleared, some attendees who stayed up late saw a demonstration of Earth's magnetospheric effects in the form of a spectacular aurora.

On Thursday, Jim Klimchuk gave a talk on magnetic reconnection in the solar corona, noting that reconnection on the Sun at the base of magnetic loops seems to be patchy and irregular. It remains to be seen whether this is an important aspect of reconnection in the magnetosphere. On the basis of the dayside tail reconnection system, Joe Kan proposed that the transport of solar wind kinetic energy by tail lobe current loops powers magnetic storms and auroral substorms by driving the global earthward convection into the inner magnetosphere and down to the oval ionosphere by field-aligned currents. Chris Chaston discussed energizing plasmas from the plasma sheet to the inner magnetosphere by kinetic Alfvén waves. Mei-Ching Fok discussed the earthward convection that dominates the storm time ring current buildup and the very low frequency waves that enhance the fluxes of relativistic electrons during storm recovery.

Katy Goodrich, University of Colorado Boulder

Auroral image taken after a record-setting snowstorm during the Chapman Conference.

The Friday session focused on preliminary MMS results, starting with an overview by Jim Burch showing features of the high-resolution data set during crossings of the magnetopause. (The MMS data are now openly available). Craig Pollock and Tai Phan gave reports on the unprecedented time scales and accuracies of MMS's plasma measurements, and Roy Torbert and Bob Strangeway reported on the spacecraft's magnetic and electric field measurements. Stephen Fuselier described ion composition effects on reconnection, and Barry Mauk and Joe Fennell described energetic particle observations.

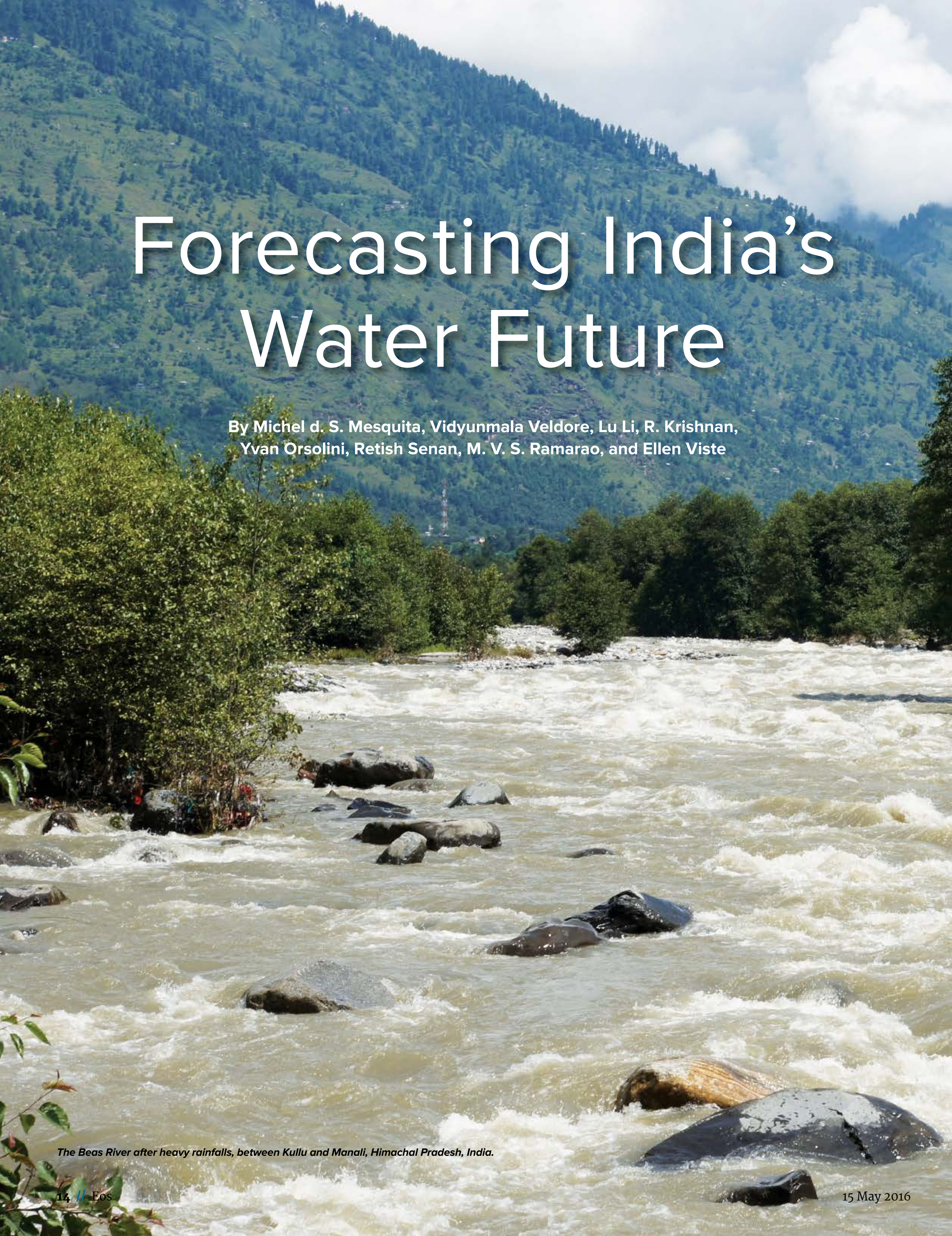
We enjoyed the conference. It provided a good assessment of our current understanding of magnetospheric dynamics. It also gave us a look at what's next in our field, now that MMS is supplying, and Juno will supply, an unprecedented depth and breadth of data.

The conference gave us a look at what's next in our field, now that the Magnetospheric Multiscale Mission is supplying, and Juno will supply, an unprecedented depth and breadth of data.

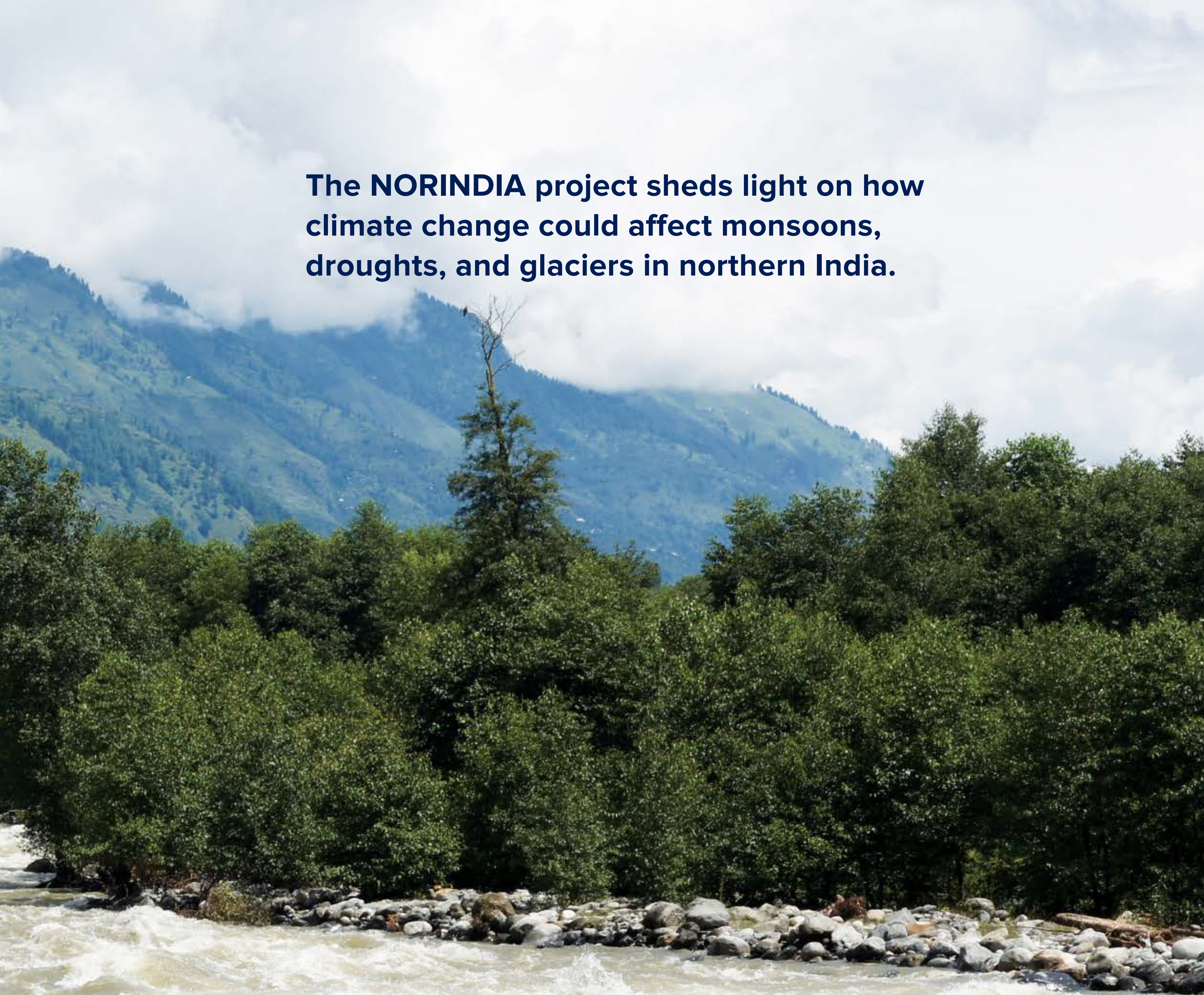
By **J. R. Kan,** Geophysical Institute, University of Alaska Fairbanks; and **J. L. Burch,** Southwest Research Institute, San Antonio, Texas; email: jburch@swri.edu

Forecasting India's Water Future

By Michel d. S. Mesquita, Vidyunmala Veldore, Lu Li, R. Krishnan, Yvan Orsolini, Retish Senan, M. V. S. Ramarao, and Ellen Viste



The Beas River after heavy rainfalls, between Kullu and Manali, Himachal Pradesh, India.



The NORINDIA project sheds light on how climate change could affect monsoons, droughts, and glaciers in northern India.

The Indian subcontinent is particularly vulnerable to climate change because of its diversified socioeconomic and climatic conditions. Changes in monsoon variability and glacier melt may lead to droughts over the Indian plains as well as extreme rains and abrupt floods in the neighboring Himalayas [*Turner and Annamalai*, 2012].

Through our work with the NORINDIA project (see http://bit.ly/NORINDIA), we found that there is a risk of 50% glacier ice loss in the Beas River basin, which covers northwestern India and northeastern Pakistan, by 2050.

Understanding the monsoon variability and the hydrological cycle in the Hindu-Kush-Himalayan region would improve our ability to forecast changes and make informed policy decisions. The objective of NORINDIA was to understand the hydrological impacts of climate change in India. The project ran from 2012 to 2015 and was funded by the Norwegian Research Council.

NORINDIA has provided a fresh hydrological assessment of water resources in India through the use of scenarios from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report and other modeling systems. The Beas River basin (Figure 1) forecast is one example of NORINDIA's work.

A Five-Part Project

The NORINDIA project was divided into five work packages (WP) that dealt with large- and small-scale atmospheric processes:

- WP1 studied the effect of climate change on the Indian monsoon.
- WP2 quantified the role of snow and surface processes on the Indian summer monsoon.
- WP3 quantified the role of snow and glacier melt on water resources.
- WP4 developed dynamical downscaled model output using the Weather Research and Forecasting (WRF) model and the atmospheric general circulation model with zooming capability, developed by the Laboratoire de Météorologie Dynamique. Known as LMDZ, the latter allows grids to be refined around specific sites.
- WP5 studied changes in the hydrological cycle in the present and future at the Beas River basin (up to Pandoh Dam) in the western Himalayas using WRF-Hydro [*Gochis et al.*, 2014] and the Soil and Water Assessment Tool model.

Changes Ahead

All the packages worked together to integrate results across different scales of time and space to produce a unified understanding of how climate change may affect the monsoon and water availability in India. The predictions pointed to changes in summer rainfall, the onset dates for snow and monsoons, and glacier mass balance.

Fig. 1. The Indus River basin, which contains the Indus River and its tributaries, including the Beas River.

In WP1, we studied how precipitation changes under the relatively aggressive IPCC Representative Concentration Pathway (RCP) 8.5 climate change scenario, which represents a possible radiative forcing (change in atmospheric energy caused by greenhouse gas emissions) of 8.5 watts per square meter in the year 2100 relative to preindustrial levels [*van Vuuren et al.*, 2011]. Our results indicate a precipitation increase of around 10% in summer rainfall during the period 2076–2096 compared with recent climate in the Indo-Pacific region. This figure agrees with previous work by *Christensen et al.* [2013].

As part of WP2, *Senan et al.* [2016] assessed the impact of springtime snow over the Himalaya-Tibetan Plateau (HTP) on the onset of the Indian summer monsoon (ISM), using land reanalyses to initialize the coupled ensemble seasonal forecasts. They showed that deep snow over the HTP in spring influenced the meridional (north-south) tropospheric temperature gradient reversal that marks the ISM onset. Composite differences based on a normalized HTP snow index reveal that in high-snow years, the monsoon onset is delayed by about 8 days, and negative precipitation anomalies, as well as persisting dry and warm surface conditions, prevail over India (Figure 2). Half of this delay can be attributed to the initialization of snow over the HTP, highlighting the importance of improving the realism of land reanalyses over that region.

In WP3, *Viste and Sorteberg* [2015] showed that increasing temperatures may reduce annual snowfall in the Himalaya-Hindu Kush-Karakoram region, in spite of a likely increase in precipitation. With the RCP8.5 scenario, we estimated a reduction in annual snowfall of between 30% and 50% in the Indus basin, 50% and 60% in the Ganges basin, and 50% and 70% in the Brahmaputra basin

(Figure 3). These results are qualitatively in line with those of *Wiltshire* [2014].

In WP4, we showed that for the less aggressive RCP4.5 scenario (radiative forcing of 4.5 watts per square meter), there is a robust increase in surface temperature compared with the present climate. For the Beas basin in northeastern India and the Brahmaputra basin covering Bangladesh, Bhutan, and southern China, we calculated the increase to be on the order of 1.8°C in 2039–2080 and 3°C in 2079–2100. For the Indus basin, between the Himalayan Mountains and the Arabian Sea, the data suggest a significant increase in surface temperature (~3°C) in 2079–2100 but not in earlier decades.

Using long-term climate observations and high-resolution model experiments, we further noted a weakening trend in the monsoon circulation and a precipitation decline over South Asia during recent decades (1951–2005). This downward trend is largely attributable to anthropogenic forcing from aerosols, land use and land cover changes, and rapid warming of the equatorial Indian Ocean [*Krishnan et al.*, 2015; *Ramarao et al.*, 2015].

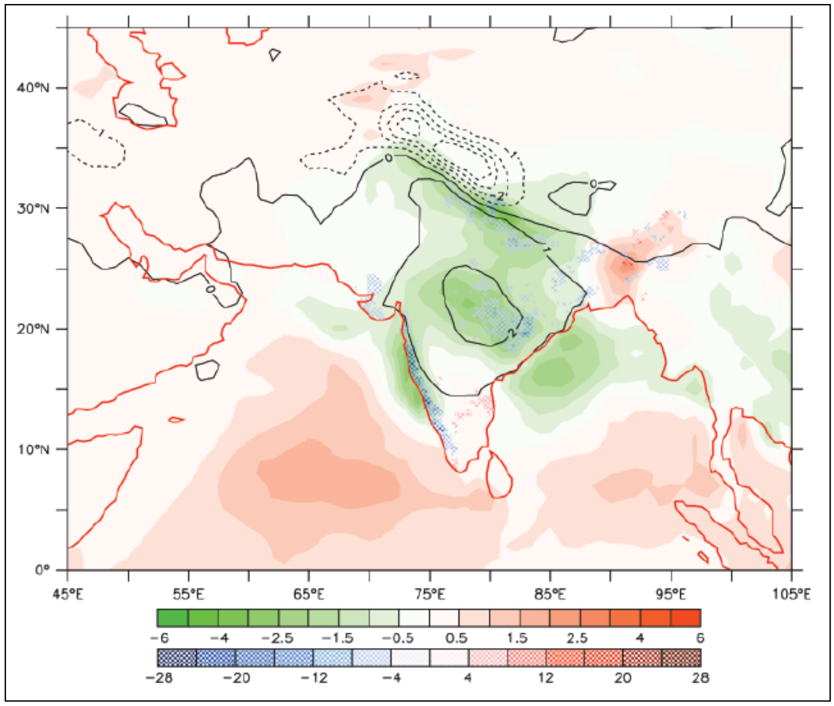


Fig. 2. High spring snow over the Himalaya-Tibet Plateau is associated with anomalously warm and dry conditions over the Indian peninsula. Contour lines indicate composite differences (in °C) in forecasted June mean temperatures at 2 meters above the surface between high and low April snow depth over the Himalaya-Tibet Plateau (27°N–40°N, 70°E–100°E) taken over the period 1981 to 2010. Color shading shows the corresponding composite difference for precipitation in millimeters per day. The 15-member ensemble seasonal hindcasts with the European Centre for Medium-Range Weather Forecasts Seasonal Forecasting System 4 were started on 1 April. The snow depths are taken from ERA-Interim/Land, a global land surface reanalysis data set. Also shown is the composite of 1–15 June averaged precipitation (millimeters per day, as colored stippling) based on gridded station rain gauge data from the Indian Meteorological Department. Data are shown only at the 95% significance level.

In addition, the experiments show that the surface-warming trend over the Indian region is accompanied by a decline in precipitation and soil moisture starting from the mid-1950s and continuing into the 21st century. Again, this result agrees with recent findings from observations [*Panda and Wahr*, 2016].

Finally, in WP5, our hydrological modeling shows that at present, the runoff (including rainfall runoff and ice and snow melt) from glacier-covered areas accounts for 28% of the total runoff measured at the Thalout station in the Beas River basin. The annual glacier imbalance accounts for about 13% of the total runoff in this area.

Climate change scenarios show that precipitation may increase about 11% by 2050 and 18% by the end of 2100. Forecasts for the year 2050 predict glacier area loss in the Beas River basin of about 47% for the RCP4.5 scenario and 49% for RCP8.5. Also, by the end of 2100, the glacier area loss in this basin is about 73% for the RCP4.5 scenario and 80% for RCP8.5. This would result in a reduction in runoff of 25% by about 2050 and 29.9% by the end of the century. These results contribute to the ongoing discussion on glacier mass balance in India [*Moors et al.*, 2011].

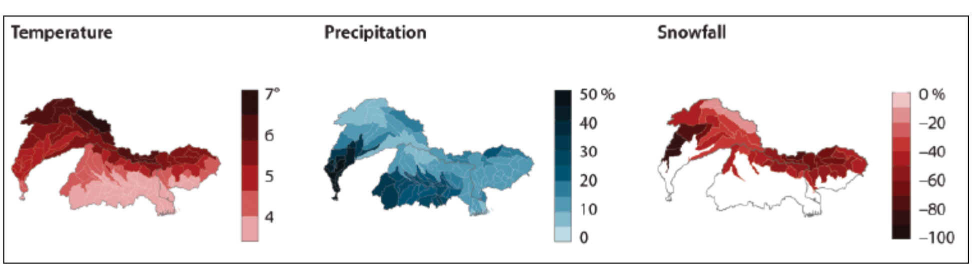


Fig. 3. Projected changes in temperature, precipitation, and snowfall in subbasins of the Indus, Ganges, and Brahmaputra basins. Data are Coupled Model Intercomparison Project Phase 5 (CMIP5) multimodel mean changes from 1971–2000 to 2071–2100, with the Representative` Concentration Pathway (RCP) 8.5 scenario; methods were described by Viste and Sorteberg *[2015].*

What We Learned

The NORINDIA project has contributed to furthering the understanding of the hydrological impacts in India under different climate change scenarios. We presented our results to stakeholders at the Norwegian Programme for

The Beas River at Mandi, Himachal Pradesh, India. NORINDIA placed special importance on assessing the future runoff of the Beas, one of the major rivers in the Indus basin, because it plays a key role in current and future plans for hydropower generation in India.

Research Cooperation with India (INDNOR; see http://bit.ly/INDNOR-programme) collaborative meeting in 2015. This meeting gathered participants from three other India-related projects to discuss changes in climate and the consequent hydrological impact. We hope that NORINDIA will make a significant contribution to stakeholders and policy makers with respect to the future of water resources in India.

A continuing project called “C-ICE: Counteracting effect of future Antarctic sea-ice loss on projected increases of summer Monsoon rainfall” (see http://bit.ly/C-ICE) has been funded, and was expected to start as the magazine went to press. The program will investigate the sensitivity of ISM to future Antarctic sea ice loss, which may partially counteract the general tendency toward increased monsoon rainfall over India and may also contribute to increasing its subseasonal variability.

Acknowledgments

We thank the Norwegian Research Council and Statkraft for providing funding to the NORINDIA project with grant 216576.

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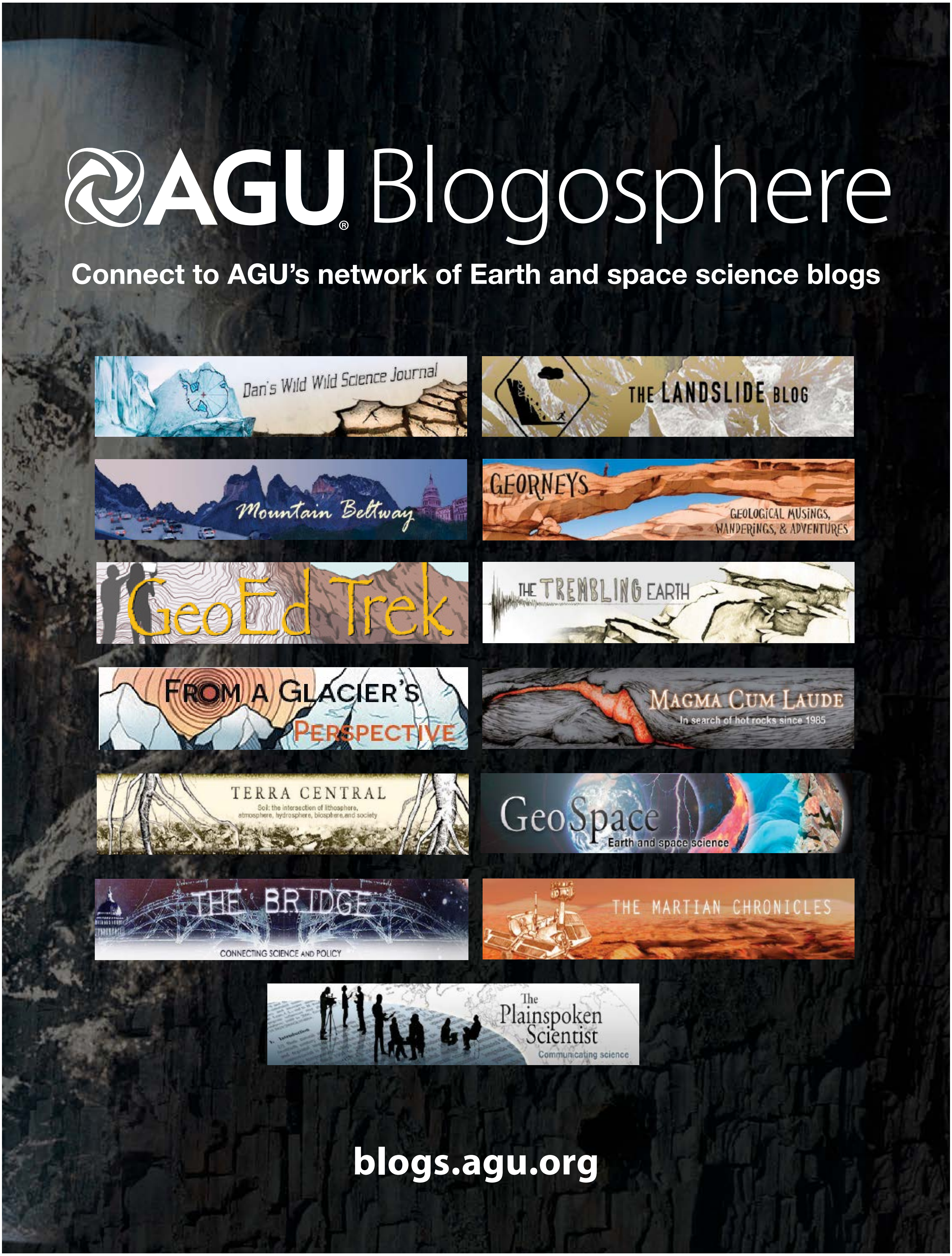
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Connect to AGU's network of Earth and space science blogs
Dan's Wild Wild Science Journal
THE LANDSLIDE BLOG
Mountain Beltway
GEORNEYS
GEOLOGICAL MUSINGS, WANDERINGS, & ADVENTURES
GeoEd Trek
THE TREMBLING EARTH
FROM A GLACIER'S PERSPECTIVE
MAGMA CUM LAUDE
In search of hot rocks since 1985
TERRA CENTRAL
Soil: the intersection of lithosphere, atmosphere, hydrosphere, biosphere, and society
GeoSpace
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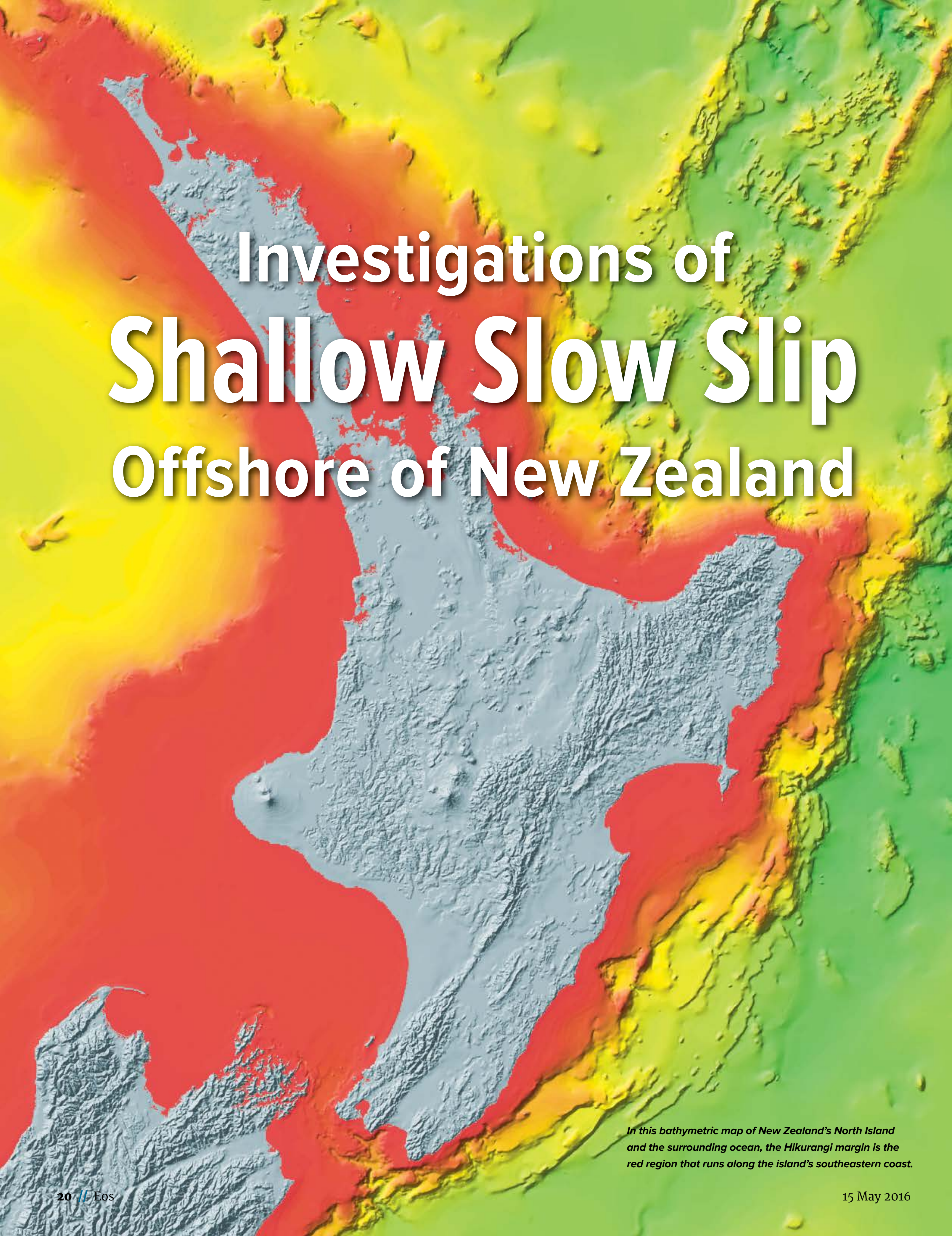
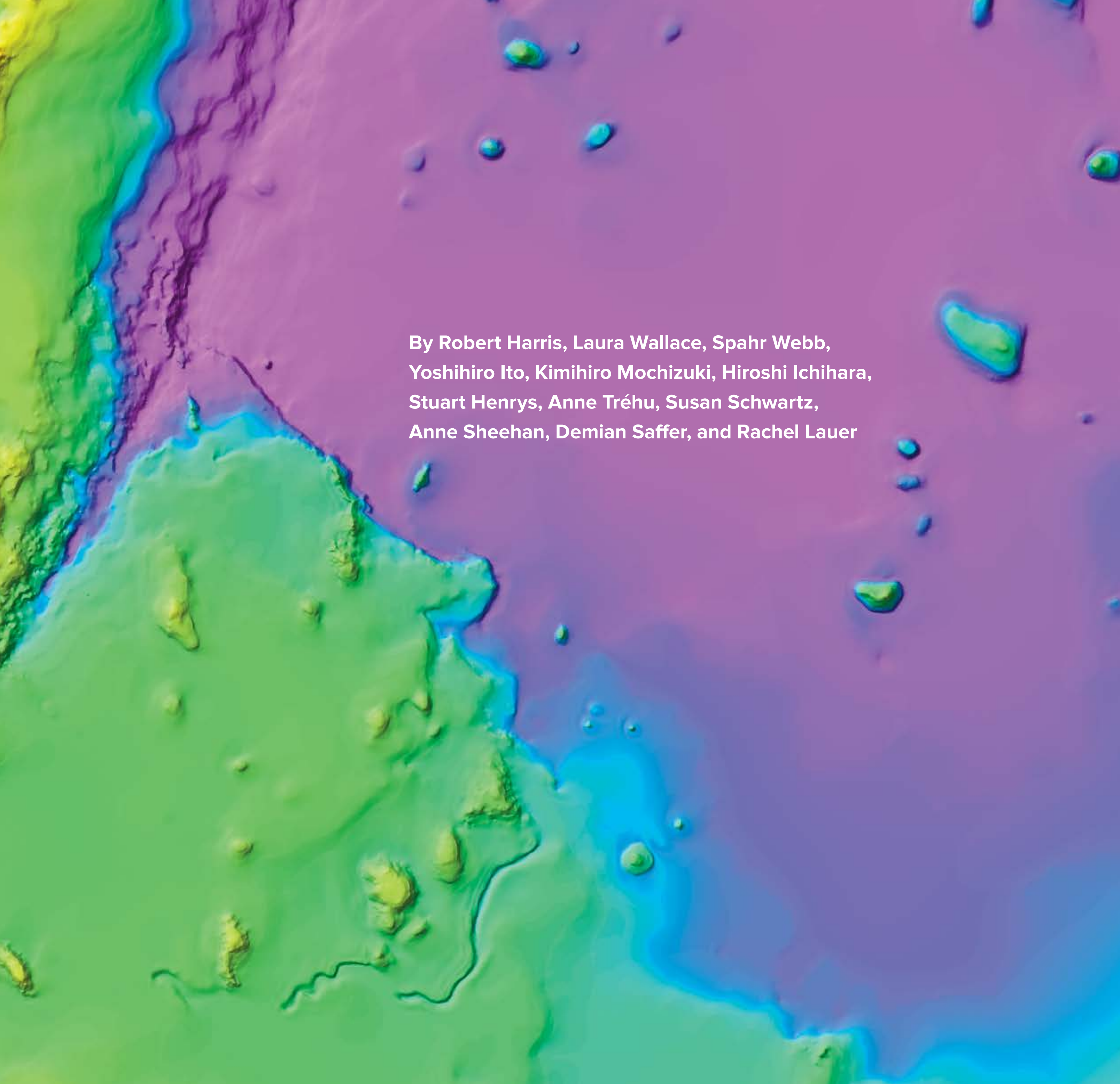
Investigations of Shallow Slow Slip Offshore of New Zealand



In this bathymetric map of New Zealand's North Island and the surrounding ocean, the Hikurangi margin is the red region that runs along the island's southeastern coast.



National Institute of Water and Atmospheric Research

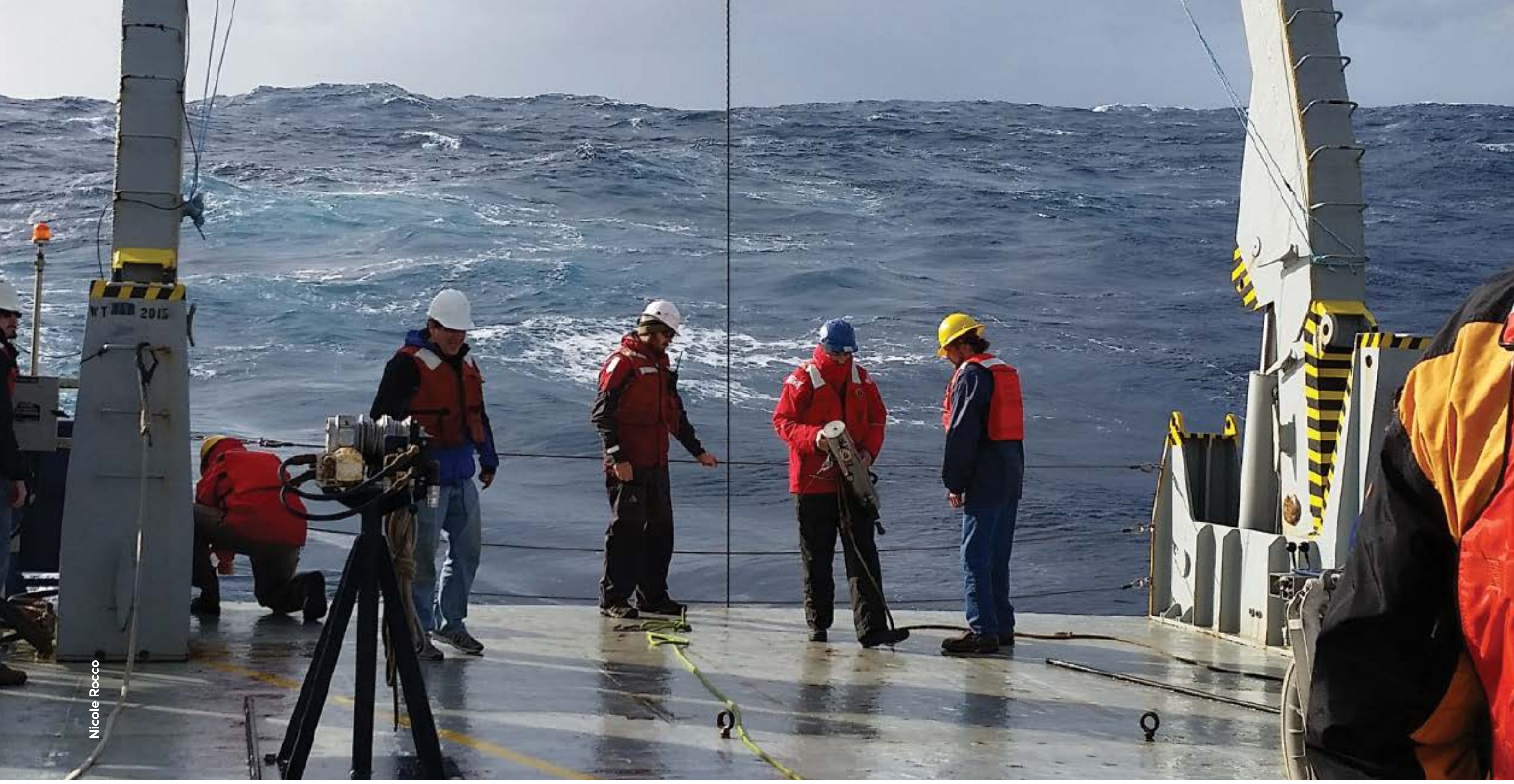
By Robert Harris, Laura Wallace, Spahr Webb, Yoshihiro Ito, Kimihiro Mochizuki, Hiroshi Ichihara, Stuart Henrys, Anne Tréhu, Susan Schwartz, Anne Sheehan, Demian Saffer, and Rachel Lauer

Two recent studies and an upcoming International Ocean Discovery Program (IODP) drilling project target a better understanding of the causes and consequences of shallow slow slip events (SSEs). These events, where crust moves at speed that is too slow to detect using seismometers, are known to occur along the Hikurangi margin, which runs along the eastern coast of New Zealand's North Island.

The uplifted Hikurangi margin provides an important location for amphibious investigations of the plate boundary and is the focus of several large-scale international investigations into shallow slow slip and the seismogenic zone. The U.S. National Science Foundation (NSF) Geodynamic Processes at Rifting and Subducting Margins (GeoPRISMS; see http://GeoPRISMS.org) program has selected this region as a focus site for its Subduction Cycles and Deformation initiative (see http://bit.ly/SCD-initiative). As GeoPRISMS activity begins ramping up at this site over the next several years, studies are already under way to help understand the spectrum of fault slip on subduction thrust faults, which generates Earth's most powerful earthquakes.

Slow Slip Events

During SSEs, millimeters to decimeters of aseismic fault slip continue over days to months at rates between long-term plate motion and seismic slip.



Nicole Rocco

The crew of the R/V Roger Revelle *waits for a heat flow probe to surface, as they recover their instruments at the end of the STINGS cruise. The crew members are about 6 feet (1.8 meters) tall, and the distance from the waterline to the deck is about 12 feet (3.7 meters).*

Although many of these events are found at depths of 25 to 50 kilometers, newly imaged shallow SSEs (less than 15 kilometers deep) provide a unique opportunity to investigate this phenomenon nearer to the source of slow slip [*Saffer and Wallace,* 2015].

Subduction thrusts host a spectrum of fault slip behaviors that range from episodic aseismic slip events, where the movement produces no earthquake activity, to the largest and most destructive earthquakes and tsunamis on Earth. SSEs often occur along portions of the plate interface where slip behavior transitions from aseismic slip to deep interseismic coupling (strain accumulation between earthquakes) and stick slip (a locking of the plate boundary between earthquakes and release of accumulated stress in earthquakes). These shallow SSEs may hold clues that increase our understanding of fault slip behavior, including earthquakes [e.g., *Schwartz and Rokosky*, 2007].

The Hikurangi Trough

The Hikurangi Trough (Figure 1) lies at the southern end of the Tonga-Kermadec subduction zone. It is the site of westward subduction of the thick and buoyant Hikurangi Plateau, an early Cretaceous (120 million years ago) large igneous province [*Davy et al.*, 2008]. The buoyancy of the Hikurangi Plateau has uplifted the fore arc, the region between the oceanic trench and its associated volcanic arc, so that the subduction thrust is located only 12 kilometers beneath the coastline.

At the northern Hikurangi subduction margin, well-documented SSEs occur at depths less than 15 kilometers approximately every 18 months. These events last for approximately 1 to 2 weeks and produce horizontal displacements of as much as 3 centimeters at onshore continuous GPS sites [*Wallace and Beavan,* 2010]. These SSEs are associated with tremors [*Kim et al.,* 2011] and elevated levels of microseismicity [*Delahaye et al.*, 2008]. In addition to the SSEs, this part of the subduction interface has generated tsunami earthquakes with a surface wave magnitude of 7.0–7.2 that originated near the trench in March and May 1947 [*Doser and Webb,* 2003].

Project Design and Technology

The Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS; see http://bit.ly/HOBITSS) offshore seismic and geodetic experiment is jointly funded by NSF, Japan, and New Zealand. This project is exploring the relationship between slow slip events, tectonic tremor, and seismicity along the northern Hikurangi margin (Figure 1).

Five short-period and 10 broadband period ocean bottom seismometers, 24 absolute pressure gauges (APGs), and three ocean bottom electromagnetic instruments were deployed in May 2014 using the New Zealand R/V *Tangaroa*. The U.S. R/V *Roger Revelle* successfully recovered all instruments in June 2015. We are using the data to investigate the offshore occurrence and distribution of slow slip and the spatial and temporal relationship between slow slip and seismicity on and near the megathrust.

One of the most exciting and novel aspects of HOBITSS is the use of a dense network of APGs (<10 kilometer spacing) to detect vertical deformation of the seafloor during large slow slip events that occurred beneath the array between late September and early October 2014. These data could reveal the detailed distribution of slow slip on the shallow megathrust for the first time.

A second research cruise, the Subduction Thrust Investigation of New Zealand using Geothermics and Seismics (STINGS; see http://bit.ly/STINGS-cruise), aboard the R/V *Roger Revelle* during May and June 2015, is the first part of a field and modeling program to investigate the temperature and seismic structures of the Hikurangi margin and their relationship to slow slip events and interseismic coupling of the subduction thrust.

Heat flow measurements, colocated with previously collected seismic reflection lines, indicate that the background

heat flow is consistent with simple models of conductive cooling in the oceanic lithosphere. In combination with global compilations of heat flow observations, such models have often led to the expectation that thermally significant fluid flow might not occur in oceanic crust older than 65 million years. However, despite the 120-million-year age of the Hikurangi Plateau, preliminary interpretation of the heat flow measurements suggests that heat transport by fluid flow is locally important in the STINGS study area.

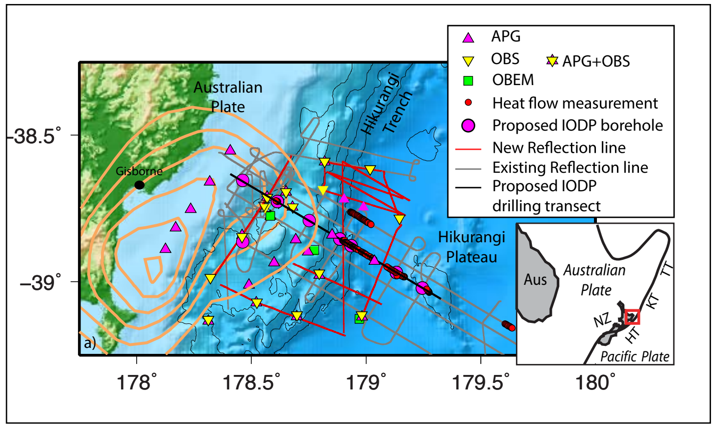


*Fig. 1. Location map of the Hikurangi Ocean Bottom Investigation of Tremor and Slow Slip (HOBITSS) and Subduction Thrust Investigation of New Zealand using Geothermics and Seismics (STINGS) experiments and the planned International Ocean Discovery Program (IODP) drilling transect. The map shows the locations of absolute pressure gauges (APG), ocean bottom seismometers (OBS), and ocean bottom electromagnetic instruments (OBEM). Orange contours show slippage distances for the 2010 slow slip event [*Wallace and Beavan*, 2010]. The maximum slip of 120 millimeters occurred within the innermost contour line. The contour interval is 20 millimeters, and the outermost contour represents 20-millimeter slip. The inset shows the experiment location: New Zealand (NZ); Australia (Aus); and the Hikurangi Trench (HT), Kermadec Trench (KT), and Tonga Trench (TT) systems.*

Future Goals

Both of these experiments are providing important context to guide planned drilling aimed at understanding the origins of slow slip. The Facilities Board for the U.S. drilling vessel *JOIDES Resolution* has committed to drilling a transect of boreholes in 2018 as a part of this project.

These boreholes will address a suite of scientific objectives. One main objective is characterizing the in situ state and composition of the incoming plate and shallow plate boundary fault near the trench. Another is installing borehole observatory instruments to measure temporal variations in deformation, hydrogeological, geochemical, and thermal conditions along a transect of holes above the SSE source.

The proximity of SSEs to the Earth's surface at north Hikurangi offers an outstanding opportunity for unprecedented high-resolution imaging of the SSE source and direct sampling of rocks and measurement of in situ properties in the slow slip event source area that is not possible in deeper SSE regions. International initiatives such as HOBITSS and STINGS, as well as planned IODP drilling and three-dimensional seismic acquisition, will help to resolve many outstanding questions about why subduction thrusts slip in slow slip events and the relationship of SSEs to larger, damaging earthquakes.

Acknowledgments

We thank the crews of the R/V *Tangaroa* and R/V *Roger Revelle* for their skill and dedication in making the cruises successful. Funding for both experiments came from the NSF through grants OCE-1355878 (L.W.), OCE-1333025 (A.S.), OCE-1332875 (S.S.), OCE-1333311 (S.W.), OCE-1355878 (R.H. and A.T.), and OCE-1355870 (R.L.); the Japan Society for the Promotion of Science, KAKENHI-26257206 (Y.I.); research funding from the government of New Zealand to GNS Science (S.H.); and Marine Funding Allocation to the National Institute of Water and Atmospheric Research (NIWA) R/V *Tangaroa*. The HOBITSS Scientific Party consisted of L. Wallace, S. Webb, S. Schwartz, A. Sheehan, Y. Ito, K. Mochizuki, S. Henrys, H. Ichihara, R. Harris, A. Barclay, C. Becerril, J. Clapp, M. Kido, T. Koczynski, W. Masterson, A. Mironov, M. Savage, S. Suzuki, T. Yagi, J. Ball, D. Haijuma, T. Kubota, J. Nakai, E. Todd, Y. Zha, S. Katakami, C. Kinoshita, S. Plescia, T. Wilson, and E. Brenner. The STINGS Scientific Party consisted of R. Harris, A. Tréhu, S. Henrys, A. Gorman, R. Lauer, B. Pramphus, H. Colella, A. Antriansian, D. Baker, and N. Rocco.

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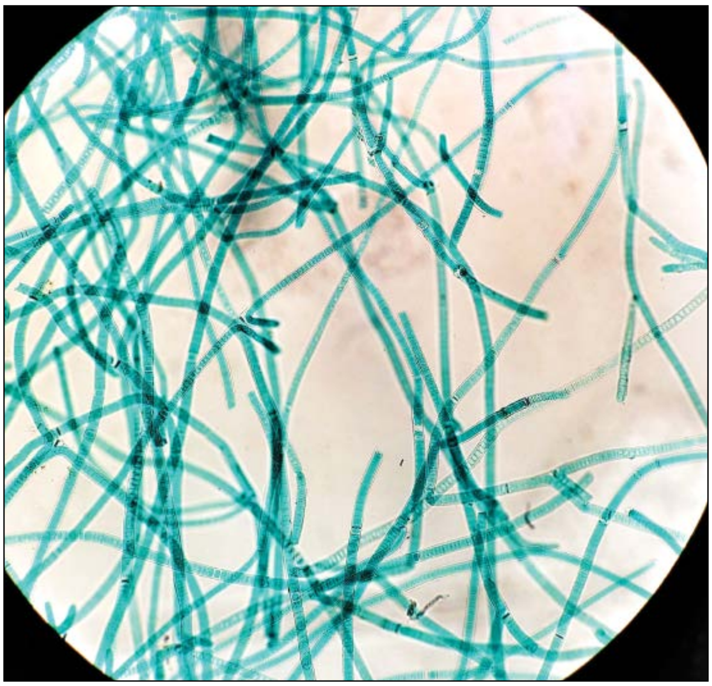
Author Tells Tale of Cellular Engines That Power Life



Matthew Parker, CC BY 3.0 (http://bit.ly/ccby3-0)

Microscopic view of a species of cyanobacteria. Cyanobacteria are thought to have been the first organisms on Earth to produce oxygen by photosynthesis.

"Let's take a moment of silence to thank our microbes," said Stefano Bertuzzi, CEO of the American Society for Microbiology (ASM). "Without our microbes, we wouldn't be here today, and you wouldn't have all this oxygen available for life."

About 150 people filled a room at AGU headquarters in Washington, D. C., on a Thursday night as Bertuzzi introduced a lecture by Paul G. Falkowski, AGU Fellow and author of the new book *Life's Engines: How Microbes Made Earth Habitable* (see http://bit.ly/Lifes-Engines).

"AGU members are not just geophysicists," said AGU's executive director and CEO Chris McEntee, sharing the introductions with Bertuzzi. "Many of our members also study how living things interact with our planet. That's why AGU is so excited to have been able to partner with ASM to present this important and exciting public lecture."

Falkowski, a biological oceanographer and professor at Rutgers University in New Jersey, took the audience on a journey from life's most primitive beginnings to today's complicated world, recounting how billions of years ago, microbes suddenly started excreting the precious oxygen humans breathe today.

Specifically, Falkowski focused on one process that all life experiences—a process of electron transfer that fuels life (see http://bit.ly/electron-xfer). In plants, this process is photosynthesis, whereby sunlight helps to convert water and carbon dioxide into sugars for the plant and a waste product called oxygen. Human cells, on the other hand, use oxygen from the air to obtain this energy. The electron transfer "machine" first evolved in microbes, Falkowski said.

"Nature made this engine once," Falkowski said, "and it's been used again and again" in a variety of forms.

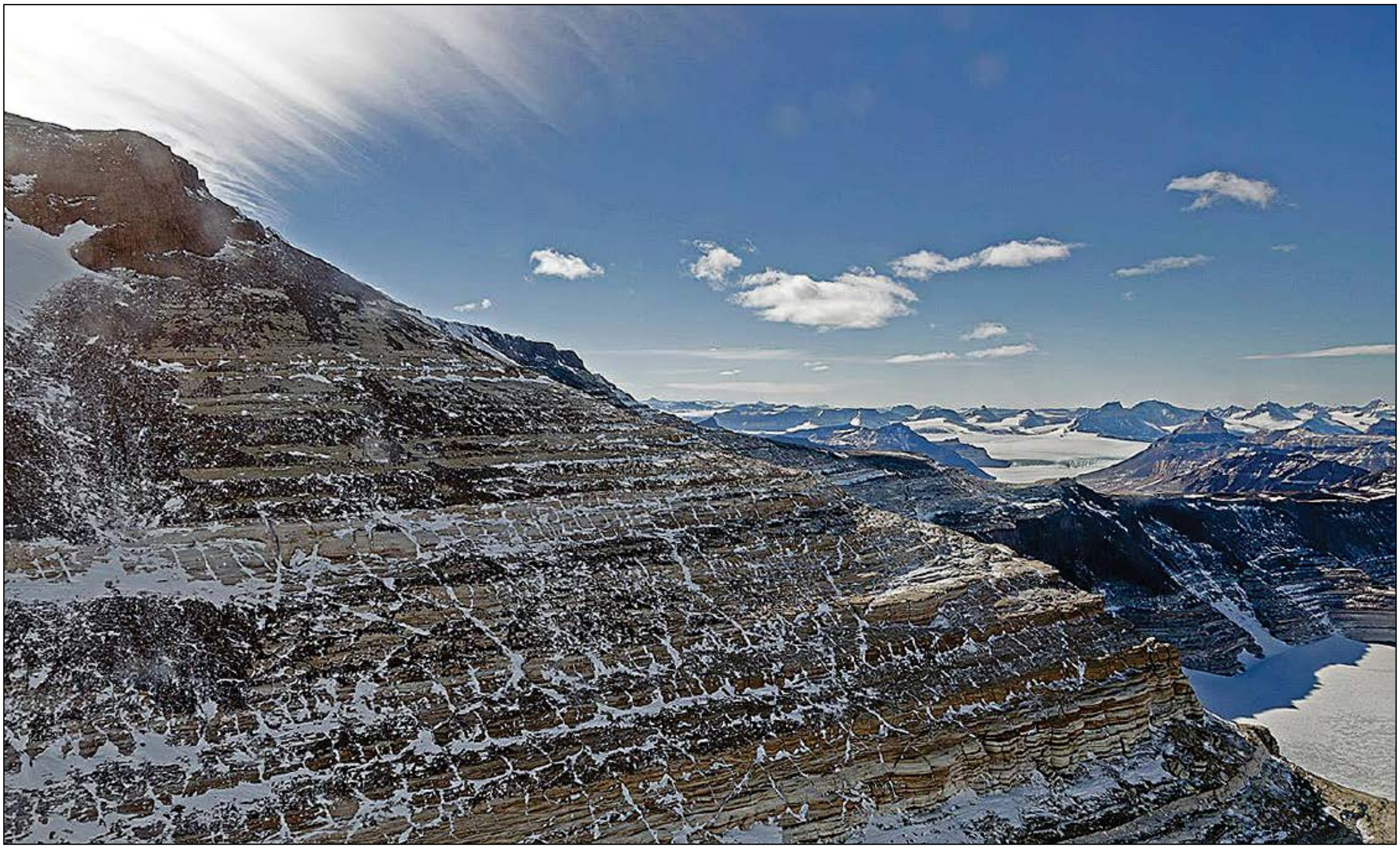
At the end of Falkowski's talk, which took place on 3 March, audience members asked questions about a myriad of topics, ranging from "Who really wrote *On the Origin of Species*?" (it was Charles Darwin) to "Will scientists find life on other planets?"—a question Falkowski thinks will be answered before researchers even figure out the origin of life on planet Earth.

"I love microbes because I grew up looking at them through Leeuwenhoek-inspired microscopes my dad made," said Lily Steenblik Hwang, a freelance science journalist who attended the lecture. "I'll probably end up buying and reading the book."

"The biggest takeaway for this book from my perspective is that we're the fragile species, that microbes are the real stewards of the planet," Falkowski told *Eos*.

By **JoAnna Wendel,** Staff Writer

Antarctica Gets a New Gravity Map



NASA/Michael Studinger

A new map of Antarctica's gravity anomalies could help scientists study mountain building in the Transantarctic Mountains.

The pull of gravity is not even across Earth's surface; in fact, your weight may change slightly depending on where you stand. The planet's uneven density gives rise to these gravity anomalies—variations in the strength of gravity over Earth's surface with respect to the smooth model of normal gravity. Relevent data are much needed in geodesy to construct high-resolution models of Earth's gravity field. Using these data, the undisturbed mean global sea level (the geoid) can be determined, and it serves as an important reference surface for height measurements and for inferring sea surface topography. Furthermore, by measuring those variations, scientists can glean important geophysical insights about subsurface structures and processes, including the structure of the upper mantle and the tectonic processes that shape Earth's geological features.

Thanks to satellite data, maps of Earth's gravity strength have become much more complete in recent years but are limited in resolution. However, terrestrial observations—made on the ground, from aircraft, or aboard ships—are still needed for high-resolution maps. But terrestrial observations can be difficult to collect, especially in remote, inhospitable regions of Antarctica.

Now, by combining many terrestrial data sets, *Scheinert et al.* have constructed a modern map of gravity anomalies across Antarctica. The map covers 10 million square kilometers—about 73% of the continent—and has a resolution of 10 kilometers.

To make the map, the team compiled all available terrestrial data from Antarctic gravity studies performed over the past 30 years. These studies used a wide variety of analytical methods, making it impossible to blend their conclusions into a single product.

Instead, the researchers focused on the original raw data, combining and processing them using consistent methods. To aid this analysis, they used a global gravity model based on observations made by the European Space Agency's GOCE satellite.

The resulting map is the most complete gravity map ever created for Antarctica. Shared publicly, it will help researchers complete the geodetic view of Earth's gravity field and study the continent's geophysical past and future. It will also enable scientists to gain a better understanding of how the continent's geological features affect glacier and ice sheet dynamics.

Additional terrestrial data are needed to close the remaining gaps in the map; for example, data are particularly lacking over the South Pole region. However, the authors say, aircraft data collection could fill in all the major gaps within the next few years. (*Geophysical Research Letters*, doi:10.1002/2015GL067439, 2016) **—Sarah Stanley, Freelance Writer**

After a Century, Restored Wetlands May Still Be a Carbon Source

Frank Anderson, USGS

A young restored wetland on Twitchell Island, California, in July 2003. Despite no major shifts in vegetation coverage from 2003 to 2012, early productivity rates were higher compared to later stages of restoration.

Freshwater wetlands are among Earth's most productive ecosystems, and the restoration of these environments—especially in temperate and subtropical latitudes—has the potential to offset greenhouse gas emissions by sequestering large amounts of carbon dioxide. However, the breakdown of organic matter in wetlands can also release methane, a much more potent greenhouse gas. Measuring the net exchange of carbon in these ecosystems is thus crucial for determining whether wetland restoration can be used as a creditable offset in a carbon trading system.

Despite the environmental and economic implications, few studies have measured the flux of carbon from restored wetlands over the time frame of a decade, let alone the 50- to 100-year verification period required for offset and trading programs. To help address this gap, *Anderson et al.* measured the size and direction of the carbon and energy fluxes from 7 hectares of wetlands restored in 1997 on peat soils in California's Sacramento–San Joaquin Delta.

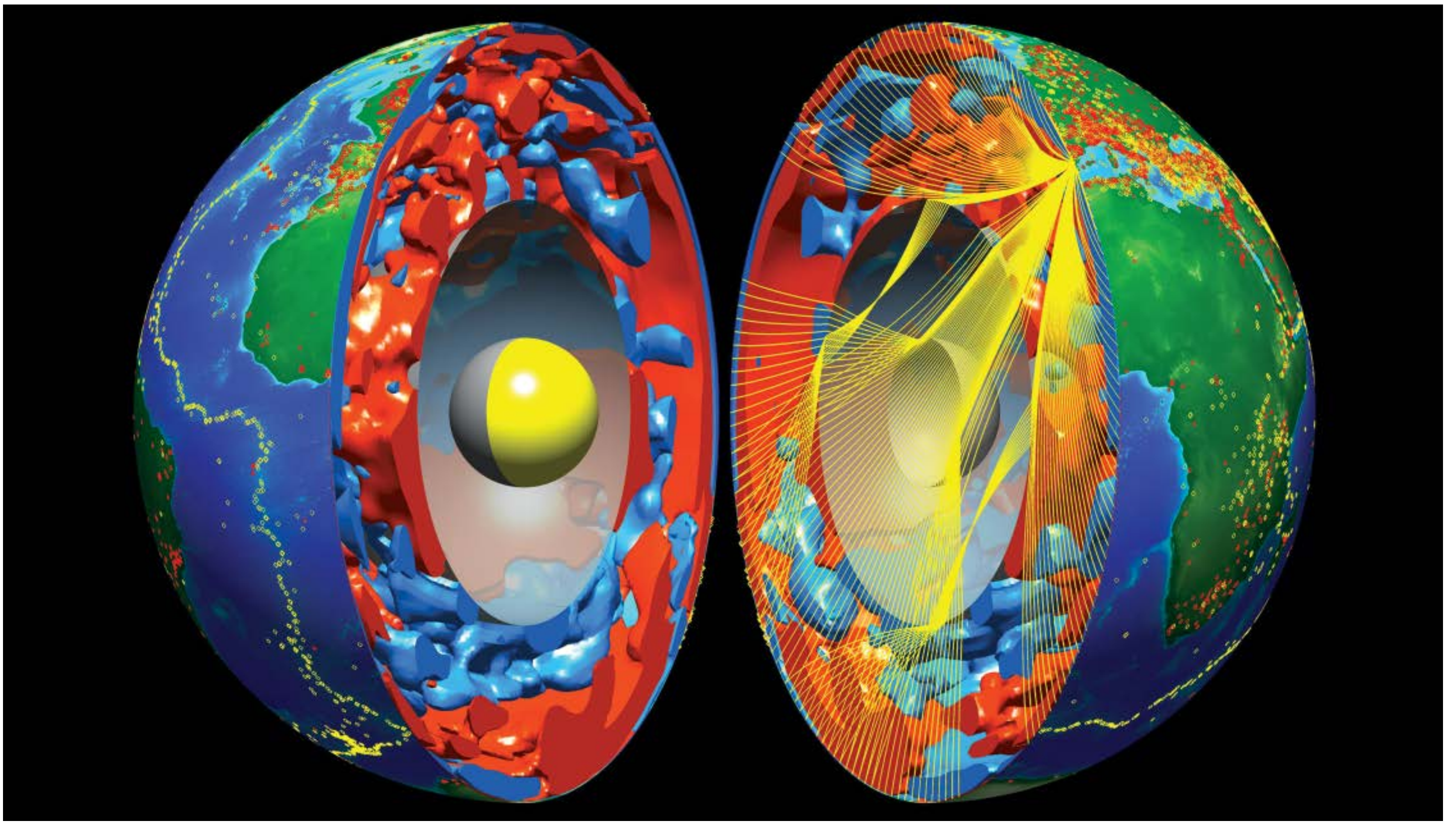
To quantify longer-term trends during different stages of restoration, the researchers measured photosynthesis and respiration for two 1-year intervals 8 years apart, once in 2002–2003 and again in 2010–2011. During the second study period the team also measured emissions of methane in order to calculate its influence on the wetlands' radiation energy balance.

The results show that when measured by mass, the restored wetlands were, on average, a small net source of carbon. The study further demonstrated that the methane emissions, which were among the highest rates ever reported, varied seasonally and significantly influenced the restored wetlands' carbon and energy balances.

Because of methane's greater greenhouse potency, the warming potential of the emissions measured during the second period greatly exceeded the potential cooling produced by the uptake of carbon dioxide during photosynthesis. Indeed, the warming potential during the 2010–2011 period was large enough to counteract the potential cooling measured during the 2002–2003 interval, when the younger wetlands were several times more productive, according to the authors.

When accounting for the 2010–2011 methane measurements as a sustained flux, the team calculated that the restored Sacramento–San Joaquin wetlands will be a source of carbon throughout the century-long time frame most relevant to carbon markets. The authors further conclude that despite its impracticability, continuous monitoring may be necessary to accurately assess the long-term sequestration potential of restored wetlands. (*Journal of Geophysical Research: Biogeosciences*, doi:10.1002/2015JG003083, 2016) **—Terri Cook, Freelance Writer**

Massive Ancient Tectonic Slab Found Below the Indian Ocean



Nathan Simmons, using MATLAB

Seismic wave velocity structure in the deep Earth revealed through seismic tomography. Earthquakes generate seismic energy near their epicenters (yellow markers), and the energy is recorded at seismic stations around the world (red markers). Seismic waves (depicted as yellow rays emanating from an earthquake beneath Spain) are disrupted as they travel through fast (blue) and slow (red) structures in the Earth. By mapping these anomalous structures on a global scale, researchers have uncovered a previously unidentified tectonic plate that sank into Earth's mantle more than 130 million years ago beneath the southern Indian Ocean.

A team of researchers recently discovered an ancient relic hidden within Earth: a tectonic plate resting beneath the southern Indian Ocean. Scientists have found other tectonic plates that sank below Eurasia and North America, but here *Simmons et al.* describe the unique structure of this newly discovered slab, which they named the Southeast Indian Slab (SEIS). The slab has at least one feature scientists have rarely seen before: It maintains its slab-like structure all the way from the upper mantle near Earth's crust down to the region where the mantle meets the planet's superheated core. The Farallon plate beneath North America is a well-known example of this—but it was expected to exist and sank much more recently than the SEIS. In addition, not only does the SEIS traverse the entire mantle, but it also becomes more vertical along one end, so much so that it stands almost vertically between the crust and core along the eastern edge, whereas the western portion is more horizontal.

Researchers can make out structures beneath Earth's crust by examining the speed at which seismic waves generated by earthquakes and similar Earth-shattering events—known as *P* and *S* waves—travel through Earth. Here the researchers used wave data from 12,607 seismic events dating back to the 1960s, collected by 7783 seismic stations around the world, to develop the model that identified the ancient slab.

Once this tectonic slab was identified, the team looked at the region's tectonic history over millions of years to determine where and when this plate was on the surface. They determined that the slab was once along the eastern portion of the early supercontinent of Gondwana. Then, sometime during the Triassic or Jurassic period, which stretched from 250 million to 145 million years ago, the slab plunged underneath another plate. They further concluded that the subduction, or the sinking of the Southeast Indian Slab beneath another plate, terminated around 130 to 140 million years ago in the Mesozoic era, around the same time that the tectonic plates under eastern Gondwana began to separate and split up the continent.

Tectonic plates usually sink into the mantle at a rate of about 1 centimeter per year or more; they don't necessarily melt but instead bunch up at the base of the mantle and eventually assimilate or become undetectable as their temperature increases. However, if the researchers accurately estimated the timing of their newly discovered slab's subduction, this slab must have stalled in a transition zone before descending deeper into the mantle, allowing the slab to persist in the mantle longer than any other known plate. (*Geophysical Research Letters*, doi:10.1002/2015GL066237, 2015) **—Cody Sullivan, Writer Intern**

U.S. Methane Emissions on the Rise

Methane is one of the most potent greenhouse gases, second only to carbon dioxide in its ability to absorb thermal radiation. It is naturally produced by wetlands, and humans emit methane in large quantities through the use of oil and gas for energy, livestock farming, coal mining, and landfills.

In recent years, methane levels have been on the rise. Global atmospheric levels rose 1%–2% in the 1970s and 1980s, leveled out in the 1990s, and then continued to rise in the 2000s. Although scientists have documented this increase, they have found it more challenging to determine which anthropogenic sources are most responsible for methane emissions because sources often overlap and are difficult to quantify.

Here *Turner et al.* obtained data from government sources, including the Greenhouse Gas Inventory of the U.S. Environmental Protection Agency (EPA), to determine how much methane the United States is contributing to global emissions. They also used data from the Greenhouse Gases Observing Satellite (GOSAT), launched into low orbit in January 2009. By examining GOSAT data for the United States from January 2010 to January 2014, the researchers could determine how methane levels fluctuated over every region in the country.


USDA/Alice Welch, CC BY 2.0 (http://bit.ly/ccby2-0)

The livestock industry is one of the major anthropogenic sources of methane. Livestock account for about a third of methane emissions in the United States, according to a new study.

U.S. EPA inventory data showed that emissions from oil and gas and from livestock each accounted for about a third of the methane produced in the United States, while landfill waste accounted for 21%–22% and coal was responsible for 10%–13% of methane emissions.

The researchers found that U.S. methane emissions have increased by more than 30% in the past decade, making the United States a hefty contributor to the global rise in emissions. It seems the increase is largely caused by sources in the central United States—the only region in the nation to show statistically significant increases in methane production. Recent increases in oil and gas production as well as shale gas production may possibly account for this change, but other sources could be involved as well. (*Geophysical Research Letters*, doi:10.1002/2016GL067987, 2016) **—Shannon Kelleher, Freelance Writer**

Variable Mantle Lies Below Ancient Pieces of Earth's Crust

When people traverse North America's Great Plains, they tread atop ancient continental blocks dating back billions of years. This old part of the continent is also very stable and is made up of three distinct cratons: the Wyoming, Superior, and Medicine Hat cratons, all of which are surrounded by slightly younger chunks of crust that latched on to them.

Typically, when something ages, it moves more slowly and begins to fade. But the mantle underneath an ancient craton rejects geriatric stereotypes and conducts seismic waves at higher velocities than neighboring youngsters. Here *Hopper and Fischer* examine how velocities vary underneath these extremely old hunks of crust and try to tease out the origins of the variations.

The researchers used converted seismic waves, specifically the Sp phase, to image the mantle beneath those relic cratons. A seismic event releases two main waves of seismic energy into the body of the Earth: slower-moving *S* waves and faster-moving *P* waves. Scientists can detect and use the waves to image interior regions of the Earth. When an *S* wave hits a boundary in velocity, some of it is converted to a *P* wave (called an Sp phase), which will hit a seismic detector before the *S* wave. Researchers can use these *S* wave precursors to image regions of the crust or mantle.

Wave imaging revealed four distinct types of velocity interfaces—or layers—in the upper mantle. One type is a drop in velocity that lies horizontally about 70–90 kilometers deep; another is a drop in velocity between 85 and 150 kilometers deep that dips downward. In these first two zones, volatile-rich minerals and/or relict oceanic crust from ancient subduction slow the propagation of seismic waves. The third type of layering exists near the base of the lithosphere—the rigid plate at the top of the mantle—and actually shows that seismic waves speed up, although it's unclear why.

Finally, the researchers looked for a velocity change at the base of the plate—the boundary between the lithosphere and asthenosphere. This boundary is clearly seen via Sp waves in young, active regions like the western United States; beneath these old cratons, however, it is generally invisible because it lacks the sharp negative velocity gradients that exist beneath young plates.

Between 85 and 150 kilometers in depth, the dipping gradients provided clues that cratonic mantle formed from subduction—their drooping shape may represent the remains of old subducting slabs. Large amounts of eclogite, a type of metamorphic rock often linked to subduction, have been found in areas above these dipping structures. The proportions of different oxygen isotopes in the eclogites suggest they were altered by seawater, implying they were part of an oceanic slab that subducted underneath the craton. These facts suggest that a person standing in the Great Plains is standing not only on a billion-year-old piece of Earth's crust but also over the remains of ancient seafloor. (*Geochemistry, Geophysics, Geosystems*, doi:10.1002/2015GC006030, 2015) **—Cody Sullivan, Writer Intern**

Glacial Meltwater Features Depend on Glacier Type and Location

Timothy Fegel

The last remnants of Teton ice glacier in the morning sun, in Grand Teton National Park in Wyoming.

At first glance, glaciers may appear lifeless, yet these icy flows bear thriving microbial communities, as well as nutrients and metals, that escape in meltwater and shape downstream ecosystems.

Not all glaciers are created equal. Different types of glaciers in different locations release different materials in meltwater. However, this variation has been poorly documented. Now *Fegel et al.* have characterized the different meltwater compositions of glaciers in the western United States. They describe which characteristics depend on glacier type, location, or both.

In the summers of 2012, 2013, and 2014, the researchers collected meltwater and sediment samples from glaciers in the Cascade Mountains, the Rocky Mountains, and the Sierra Nevada Mountains. These regions feature different climates, slopes, elevations, and underlying rock. The team examined 25 classic alpine flows and 24 rock glaciers, which consist of coarse rock fragments bound together and lubricated by ice.

For all three regions, rock glacier meltwater was warmer, less acidic, and more conductive than ice glacier meltwater. Rock glacier meltwater also had higher concentrations of silica; total dissolved nitrogen; nitrate; and calcium, potassium, magnesium, and strontium ions. Ice glacier meltwater had higher levels of ferric iron, manganese (II), and ammonium. The scientists also found different organic (carbon-related) characteristics for rocky glaciers versus ice glaciers.

Ribosomal DNA sequencing revealed different microbial community compositions between rock glacier and ice glacier meltwaters as well. Rock glacier microbial communities were more diverse than ice glacier communities, and certain species were abundant in meltwater from both glacier types.

When the team considered regional differences, they also found location-specific trends in temperature, conductivity, metal concentrations, and nitrate and ammonium concentrations. Dissolved organic carbon levels did not vary by location, but other organic matter characteristics did. Microbial community composition also varied on the basis of region, with the Rocky Mountain samples being the most diverse.

The results suggest that glacier type determines the concentration of released substances and the complexity of released organic materials. Meanwhile, geographic region dictates which rock type is weathered and the rate and intensity of weathering.

Geographic region also affected the concentration of nitrogen-bearing compounds in meltwater samples. The scientists suggest that this is because of region-specific differences in atmospheric nitrogen incorporated into the glaciers. In fact, glacier meltwater composition may give a lagging signal of earlier location-specific anthropogenic increases in atmospheric nitrogen and other substances.

With 10,000 rock glaciers identified in the United States, they are 5 times more common than alpine ice glaciers in some areas. In coming centuries, rising temperatures will melt rock glaciers and ice glaciers alike. However, rock glaciers melt more slowly and will likely stick around after ice glaciers disappear. Knowing their meltwater composition will help predict how they will alter downstream ecosystems in the future. (*Journal of Geophysical Research: Biogeosciences*, doi:10.1002/2015JG003236, 2016) **—Sarah Stanley, Freelance Writer**

ENVIRONMENTAL SCIENCE

Faculty Position

The South University of Science and Technology (known as SUSTC or SUSTech) (http://www.sustc.edu.cn/en) is a public university founded in the Shenzhen Special Economic Zone of China. It is intended to be a top-tier international university that excels in interdisciplinary research, nurturing innovative talents and delivering new knowledge to the world. SUSTC is conducting a global search for talented faculty who are also innovators and trailblazers. School of Environmental Science and Engineering at SUSTC invites applications for tenure-track and tenured faculty positions in broadly defined environmental science and engineering. Positions are immediately available at all ranks. Highly competitive salaries and start-up packages will be provided. The successful candidates will have great opportunities to advance environmental research in China as the country faces up to enormous challenges in achieving environmental sustainability.

Applicants should have a Ph.D. degree in a water, air, or earth system related discipline. Candidates must have a proven track record of high-quality scientific publications and must have excellent communications skills. Those interested are invited to apply by submitting the following material electronically to iese@sustc.edu.cn: 1) Curriculum Vitae (with a complete list of publications); 2) Statement of research interests; 3) Statement of teaching philosophy; 4) Selected reprints of three recent papers; and 5) Names and contact information of five references. Review of applications will begin immediately and continue until the positions are filled.

OCEAN SCIENCES

OCEAN SCIENCES - PROGRAM STUDY

Theoretical/modeling postdoc in physical oceanography - Program in Atmospheric and Oceanic Sciences (AOS) at Princeton University

The AOS ocean biogeochemistry/physics group seeks outstanding postdoctoral scholars to participate in studies aimed at understanding the global ocean heat, carbon, and biogeochemistry cycles and their association with ocean circulation and the large-scale climate system. Preference will be given to candidates with a strong background in theoretical physical oceanography along with numerical modeling skills. We encourage candidates interested in addressing fundamental research questions relevant to physical and biogeochemical aspects of ocean and climate dynamics.

Individuals will join a vigorous interdisciplinary research group under the direction of Prof. Jorge Sarmiento and Dr. Stephen Griffies, and will be able to collaborate with a wide range of researchers at Princeton University and NOAA/GFDL, as well as external collaborators at the member institutions of the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) project sponsored by NSF Polar Programs. Available resources include realistic and idealized climate and earth system models, including state-of-the-science models with active mesoscale features allowing for research into the role of eddies in climate and biogeochemical dynamics. Resources also include compilations of high quality global biogeochemical data sets, as well as the opportunity to participate in the SOCCOM initiative aimed at dramatically increasing Southern Ocean observations and modeling making use of autonomous biogeochemical-Argo floats.

Candidates must have received a Ph.D. in physical oceanography, applied mathematics, or theoretical physical sciences within three years of the appointment start date. Training in theoretical physical oceanography, ocean circulation, ocean biogeochemistry, and/or climate change are very useful, along with strong modeling, quantitative, and statistical skills. An ability and interest to work across disciplines is highly desirable. The term of the appointment is for one year with the possibility of renewal based on satisfactory performance and continued funding.

Applicants are asked to submit a vitae, a statement of research experience and interests, and names of at least 3 references to http://jobs.princeton.edu, Req.# 1600316. Review of applications is immediate and will continue until the positions are filled.

These positions are subject to the University's background check policy.

Princeton University is an equal opportunity/affirmative action employer and all qualified applicants will receive consideration for employment without regard to race, color, religion, sex, sexual orientation, gender identity, national origin, disability status, protected veteran status, or any other characteristic protected by law.

Faculty Positions in Environmental Science and Engineering South University of Science and Technology in Shenzhen, China

The South University of Science and Technology (known as SUSTC or SUSTech) (http://www.sustc.edu.cn/en) is a public university founded in the Shenzhen Special Economic Zone of China. It is intended to be a top-tier international university that excels in interdisciplinary research, nurturing innovative talents and delivering new knowledge to the world. SUSTC is conducting a global search for talented faculty who are also innovators and trailblazers. Founded since 2015, the School of Environmental Science and Engineering at SUSTC aspires to become a center of excellence for cutting-edge and multidisciplinary environmental research. We invite applications for tenure-track and tenured faculty positions in broadly defined environmental science and engineering. Research areas include but are not limited to: hydrology and water resource engineering, water pollution and treatment, atmospheric chemistry, air pollution control, solid waste utilization, ecosystem assessment, environmental remote sensing, and global change. Positions are immediately available at all ranks. Highly competitive salaries and start-up packages will be provided. The successful candidates will have great opportunities to advance environmental research in China as the country faces up to enormous challenges in achieving environmental sustainability.

Applicants should have a Ph.D. degree in a water, air, or earth system related discipline. Candidates must have a proven track record of high-quality scientific publications and must have excellent communications skills. Those interested are invited to apply by submitting the following material electronically to iese@sustc.edu.cn: 1) Curriculum Vitae (with a complete list of publications); 2) Statement of research interests; 3) Statement of teaching philosophy; 4) Selected reprints of three recent papers; and 5) Names and contact information of five references. Review of applications will begin immediately and continue until the positions are filled.

Assistant/Associate/Full Professors - Physical and Biological Oceanography, Marine Geophysics/Geology, and Ocean Engineering

South University of Science and Technology of China

The school of oceanography at the South University of Science and Technology of China (SUSTC) invites applications for several tenure-track (or tenured) faculty positions at the ranks of Assistant, Associate, and Full Professor. Applicants must have earned Doctoral degrees in marine geophysics/geology, physical oceanography, biological oceanography, ocean engineering or closely related field. Successful applicants will be expected to establish a robust, externally funded research program and demonstrate a strong commitment to undergraduate and graduate teaching, student mentoring, and professional service. These positions will be open until filled.

SUSTC is a young university at Shenzhen in southern China since 2010 which is set to become a world-leading research university, to lead the higher education reform in China, to serve the needs of innovation-oriented national development and the needs of building Shenzhen into a modern, international and innovative metropolitan. These positions are created with a significant development to establish a vigorous research program in oceanography at SUSTC to serve the national call for China's important role in deep sea research and resource-oriented exploration in the world oceans.

To apply submit a cover letter, complete vitae with list of publications, and three names of references via http://talent.sustc.edu.cn/en/, or to Dr. Y. John Chen, Chair Professor at School of Oceanography, South University of Science and Technology of China, No 1088, Xueyuan Rd., Xili, Nanshan District, Shenzhen, Guangdong, China 518055.

2-YEAR POSTDOCTORAL POSITION IN SUBDUCTION ZONE RELATED SEISMOLOGY

LOWER HUTT, NEW ZEALAND

GNS Science, a crown research institute of New Zealand that provides Earth, geoscience and isotope research, invites applications for a two-year postdoctoral position to conduct research on recently acquired ocean bottom seismometer and absolute pressure gauge data from the Hikurangi Margin. The data capture one of the largest shallow Slow Slip Episodes to date and provide an enticing opportunity to search for temporal changes in physical properties associated with deformation on a megathrust fault. Potential avenues of research include ambient noise imaging, numerical wave propagation, and earthquake analysis. The postdoctoral project is part of a multinational collaboration with colleagues from the University of Tokyo and Dublin Institute for Advanced Studies and provides opportunities for close interaction with these institutes.

Highly motivated candidates with strong physics, computing, and proven writing skills are encouraged to submit a Curriculum Vitae, brief statement of research interests via our careers page **https://careers.sciencenewzealand.org/gns-science/gns-science-jobs**

For further information, please contact Bill Fry at: **b.fry@gns.cri.nz**

www.gns.cri.nz

We are committed to the health and safety of our employees.

University of Manitoba

TENURE-TRACK FACULTY POSITION IN SEDIMENTOLOGY DEPARTMENT OF GEOLOGICAL SCIENCES POSITION NUMBER: 20719

The Department of Geological Sciences at the University of Manitoba invites applications for a tenure-track position at the rank of Assistant Professor beginning as early as January 1, 2017 in the general area of clastic sedimentology. We especially welcome applications from candidates with research interests in resource geoscience or basin analysis. Particular attention will be given to candidates that complement on-going research and teaching activities in the Department. Qualified applicants must have a proven record of excellence in research and the potential for excellence in teaching. The successful applicant will be expected to teach undergraduate and graduate courses in sedimentology, basin analysis and field geology, and establish an internationally recognized, externally funded research program. Additional teaching may include courses in resource geoscience and stratigraphy.

The Department of Geological Sciences is home to 12 tenured and tenure-track faculty members in the Clayton H. Riddell Faculty of Environment, Earth, and Resources, and offers a range of undergraduate and graduate programs in Geology and Geophysics. It has a well-established national and international research reputation with strengths in mineralogy, geochemistry, sedimentary geology, paleontology, geophysics, and environmental geosciences. The department has over $10 million of equipment housed in major, multi-user laboratories. To learn more about the University of Manitoba and the Department of Geological Sciences, please visit: **http://umanitoba.ca/geoscience/**

Applications, as a single pdf file, should include: a cover letter outlining specific interests in the position, a detailed curriculum vitae, a statement of teaching philosophy and interests, a research plan, and the names and contact information for three references.

Applications must be sent electronically by **June 30, 2016** to **Ms. Pam Achtemichuk, Department of Geological Sciences at Pam.Achtemichuk@umanitoba.ca. Please refer to Position Number: 20719 in the application.**

Review of applications will begin July 2016.

The University of Manitoba is strongly committed to equity and diversity within its community and especially welcomes applications from women, members of racialized communities, Indigenous persons, persons with disabilities, persons of all sexual orientations and genders, and others who may contribute to the further diversification of ideas. All qualified candidates are encouraged to apply; however, Canadian citizens and permanent residents will be given priority.

Application materials, including letters of reference, will be handled in accordance with the protection of privacy provision of *"The Freedom of Information and Protection of Privacy Act"* (Manitoba). Please note that curriculum vitae may be provided to participating members of the search process.

For more information on this and other opportunities, please visit: umanitoba.ca/employment

Postcards from the Field

Installing thermohygrometers in the branches of dead *Juniperus turbinata* trees on El Hierro (Canary Islands in Spain). In this experiment, we attempt to study the extreme bioclimatic conditions of the *J. turbinata* on the island of El Hierro. The current spatial distribution of *J. turbinata* on the island is very small as a result of heavy exploitation over several centuries. The recovery of its natural habitat is of great environmental and scenic interest because it is a protected species in Europe. The research project is led by Dr. Montserrat Salvà and is titled JUNITUR+. Physical geographers and biologists from the University of Barcelona and the island council of El Hierro are involved in the project.

Wish you were here,
JUNITUR+ team
Photo author and credit: Dr. Joan A. Lopez-Bustins, Climatology Group, University of Barcelona (UB), Catalonia, Spain. Researchers in the photo: Dr. Montserrat Salvà and Ferran Salvador, UB.

View more postcards at
http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field.

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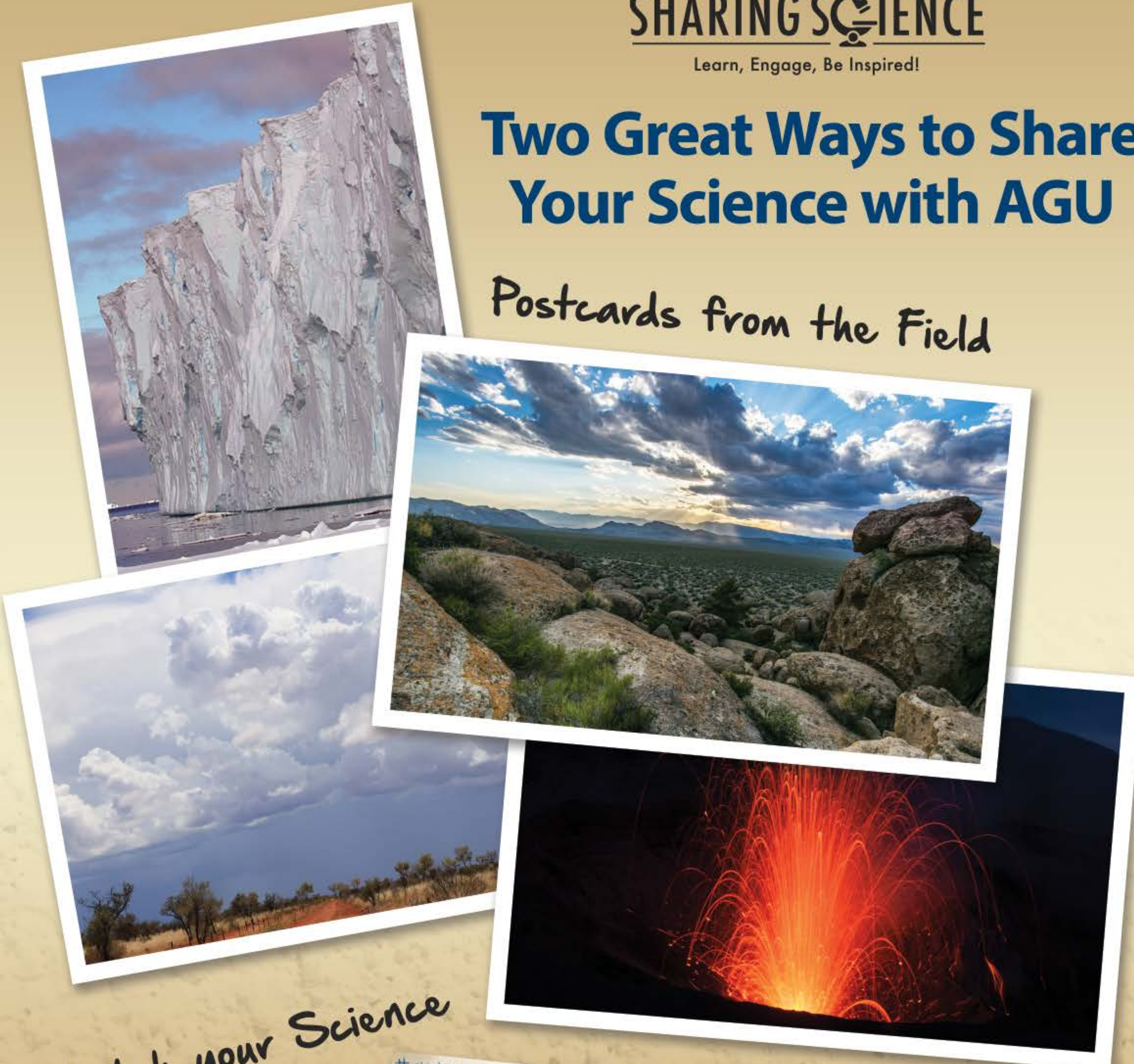
Postcards from the Field



Sketch your Science

View postcards and sketches as well as submission guidelines at
americangeophysicalunion.tumblr.com

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